THE INFLUENCE OF NITROGEN FERTILIZERS ON THE SHIPPING AND KEEPING QUALITIES OF FRUITS

by

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THE INFLUENCE OF NITROGEN FERTILIZERS ON THE SHIPPING AND KEEPING QUALITIES OF FRUITS

Introduction

Although many investigators have studied the effects of various fertilizers on the growth and production of fruit plants, and in the majority of cases have reported marked stimulation to growth and yield following applications of nitrogen, yet prior to the beginning of this study (1927), very little research work had been reported concerning the influence of these fertilizers on the firmness of flesh and storage qualities of the fruits of such plants.

For several years, reports have been circulated throughout the leading fruit producing sections of the country to the effect that the application of nitrogen-carrying fertilizers to the fruit trees is detrimental to the carrying quality and subsequent storage life of the fruit. Such propaganda was especially prevalent in the Shenandoah-Cumberland fruit section. In 1926 and 1927, buyers of fruit in this section were in some cases actually reducing the price offered for fruit produced by growers who were using nitrogen-carrying fertilizers.

In the Shenandoah-Cumberland Valley fruit section, it is necessary to apply considerable quantities of

nitrogen in order to get profitable yields. If nitrogen applications were injurious to the keeping quality it would be necessary for the growers to use that quantity of nitrogen which would give as great a yield as possible, yet resulting in as little injury as possible to the keeping quality of the fruit.

Because of the great economic importance of the question to both growers and buyers of fruit, it seemed highly desirable that some careful studies be conducted to determine the actual effect of nitrogen fertilizers, as well as other fertilizers on the various fruits.

Review of Literature

Most of the work dealing with the effect of fertilizers on the keeping qualities and firmness of flesh of fruits, has been performed in the last three or four years. Reports dealing with the subject prior to 1928 have been largely the result of observations in connection with growth and yield studies in fertilizer experiments with fruit trees.

Chandler (6) reports in 1913 as follows: "In fertilizing with nitrogen, however, to keep up the vigor of the trees, caution should be used because heavy applications of nitrogen bearing fertilizers seriously injure the color of the fruit borne the summer following and cause the fruit to rot. . . . . Increasing the vigor by pruning does not have this effect to any appreciable extent, but generally tends

to improve the quality of the fruit by increasing its size." Crane (9) found that nitrogen reduced color and delayed maturity with peach trees. McCue (27) reports that leguminous cover crops retard maturity with peaches, and that peaches grown under retarded conditions have inferior quality. Szymoniak (36) reports that phosphorus was distinctly beneficial in increasing size and firmness of strawberries, and in reducing the proportion of culls.

Haynes and Archbold (15) working in England found poor keeping quality of apples to be associated with a high nitrogen and a low sugar content of the fruit. Kidd and West (17) (18) also working in England, found a postive correlation between the nitrogen content of apples and the respiration rate in storage. These investigators also note the great variability existing between individual apples.

Appleman and Conrad (3) show that there is a close correlation between the formation of soluble pectin from insoluble protopectin, and the degree of softening of peaches during the ripening process, and conclude that this change is the chief process responsible for the softening.

Nightingale, Addoms and Blake (30) working with Elberta peaches, report"that on July 22 the flesh of fruits C (high in carbohydrates and low in nitrogen) contained nearly 100 per cent more protopectin and a higher percentage of cellulose than the flesh of fruits N (high in nitrogen low in carbohydrates)." But on August 20, this condition

was reversed, though not to the same degree. They report further that when the fruits were at the best eating condition, the fruits C contained a little higher percentage of protopectin and cellulose than fruits N, and fruits C were a little firmer as indicated by pressure tests. Fruits C were higher in sugars than fruits N.

Kimbrough (20) reports that weather conditions probably have more effect on the composition of strawberries than do the applications of fertilizers. Kimbrough (19) also found fertilizers to have no effect on the keeping quality of watermelons.

Gourley and Hopkins (13) find no effect of nitrogen on the keeping quality of apples, even though the nitrogen content may be increased as much as 100 per cent.

Magness and Overley (26) find no significant difference in the rate of softening of apples due to the application of fertilizers. Lagasse (22) reports that nitrogen applications as great as twenty pounds of sodium nitrate per tree had no influence on the keeping quality of Yellow Transparent apples, Knowlton and Hoffman (21) report that nitrogen applications have resulted in slightly softer fruit than was obtained from check plots. They conclude, however, that the differences which they obtained are not of economical importance. These investigators used orchard run fruit with the exception of extremely large or extremely small fruits. Plagge (33)

reports that the application of nitrogen to mature Jonathan and Grimes trees has considerably increased the susceptibility of the fruit to soggy breakdown. Wallace (37) working in England reports that "grassing" the orchard reduces the nitrogen content of the fruit and greatly prolongs its storage life. His sample consisted of "typical" fruit of the treatment. Shoemaker and Greve (35) find fruits from nitrated plots to be slightly softer than fruits from check plots. These investigators, however, found no correlation between the pressure test results and shipping test.

General Scope of the Investigation

The present investigations were begun in 1927.* It was planned to study the problem from three angles. First, the effect of the fertilizers on the keeping quality as measured by the pressure tester, and counts of the number of fruits which were sound, decayed scalded, etc. in storage. Second, the effect of the fertilizer on the carrying quality of the fruit as indicated by shipping tests and the pressure tester. Third, chemical and respiration studies of the fruit at picking time and during storage in an attempt to tie up chemical composition and chemical changes of the fruit in storage, with any differences in keeping quality or carrying quality, as

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*The work in 1927 was carried on by Dr. E. C. Auchter and Dr. A. Lee Schrader.

measured by physical means as outlined above.

Because of the expense involved, extensive shipping tests were not made. It has been assumed, however, that the firmness of the flesh as measured by mechanical pressure testers is an adequate measure of the carrying quality of fruit. No pressure tester was found to be satisfactory for strawberries, so it was necessary to rely principally on storage tests for this fruit.

The trees from which fruit was obtained for this study were trees which had been used by the department of horticulture for studies concerning the effects of fertilizers on growth and yield. As a consequence many of the trees had received their respective fertilizer treatments since 1922.

It is particularly advantageous, when studying the effect of fertilizers on the fruit, to have trees which have received their respective fertilizer treatments for several years. There is little question then, but that the trees are in that state of vigor which would be induced by the fertilizer treatment. If fertilizer had any effect on the keeping quality of the fruits it would be evident in fruits from such trees.

The fertilizer plots, from which fruit was obtained for this investigation, were located in apple and peach orchards and strawberry plantings, owned by commercial fruit growers throughout the state. Soil types varied from the sandy and sandy-loam soils of the Eastern Shore

to the heavy clay and shaley loam soil of Western Maryland.

For cold storage work, several commercial storage houses were used, so the fruit was actually subjected to conditions as they exist in fruit trade.

I. APPLE INVESTIGATIONS

Apple investigations were conducted in five orchards located on soils varying from the light sandy soils of the Eastern Shore, to the heavy clay loam soils of western Maryland.

Williams, Stayman and York apples were studied during the seasons of 1927, 1928, 1929, and 1930.

Methods of Study

Method of Obtaining Sample of Fruit for Storage. There has been considerable controversy regarding the proper method of securing samples of fruit for storage investigations. There are three general methods which have been employed, each of which has its good points.

1. The sample is selected at random from the fruit of the plot.

2. The fruit is selected at random, and subsequently divided into groups according to size, color, etc. each group being treated separately.

3. The sample is selected for uniformity of size, color, maturity, etc. at the time of picking.

The first method has been used recently by

Knowlton and Hoffman (21) who state: "The authors did not select uniformly colored apples from the trees receiving the several treatments, because it was felt that such a method would not yield the information that would be of practical value to the grower."

A sample selected according to the first method contains fruit ranging from the most mature to the least mature, from the smallest to the largest, and from the most highly colored to the least colored fruit in the plot at the time of picking. Since all of these factors are known to influence the keeping quality, it is obvious that the keeping quality of the sample will be influenced by the proportion of ripe to green fruit, etc. Such a sample should not be used when comparing the keeping quality of fruit from different fertilizer plots, since the presence of so many variables makes it difficult to evaluate the effect of the fertilizer on the firmness of the flesh and on the storage quality. Especially is this true where it is necessary to use small samples.

A sample selected according to the second method is as variable as the first; however by dividing the sample into groups, much of this variability can be measured. This method was used for the work on York apple in connection with this problem in 1927. It requires more fruit and more labor and equipment than either of the other two.

The third method is the one followed in this

work and the author believes it to be better under practical conditions than either of the other two. When this method of sampling is used, the effect of size, color, and degree of maturity on the keeping quality is eliminated by selecting uniform fruit and picking damage is minimized. With this type of sample, all the known variables are eliminated to a large extent, except the one which is being studied, and any differences which appear can be attributed to this variable. This is the method also followed by Magness and Overley (26), and corresponds to the method followed by a grower who carefully spot-picks his fruit.

In order to get a perfectly uniform sample, the method described by Magness et.al (25) was used, that is, each person picked a few fruits from each tree, from which fruit was being taken. The sample for storage then consisted of one to four baskets, each of which contained a composite sample of the fruit picked by all the pickers.

Ground color was used as the measure of maturity.

Pressure Testing. A sample for pressure testing consisted of fifteen apples, selected at random from the storage sample. A section of the skin, about the size of a dime, was removed from three places, equidistant around the apple, and the firmness of the flesh was measured by means of a mechanical pressure tester, -- the Magness and Taylor tester (24). The pressure test of the fruit at each inspection is the average value of forty-five determinations on fifteen apples.

Chemical Methods. A detailed description of the chemical methods is found in the appendix.

WILLIAMS APPLES, BERLIN

Description of Orchard and Plots. This orchard owned by Harrisons' Nurseries, was located at Berlin in Worcester County, Maryland on the Eastern Shore. Fertilizer treatments began in 1922, when the trees were twelve years old. The soil was a level Sassafras fine sandy loam,* and a system of clean cultivation and cover crops had been employed.

At the beginning of this investigation some plots received ten pounds of sodium nitrate per tree, while others received the equivalent of this quantity of nitrogen in the form of ammonium sulfate. When phosphorus was used in addition to nitrogen, ten pounds of acid phosphate were applied per tree. All the fertilizer was applied about three weeks before blossoming and was applied, uniformly under the spread of the limbs. Ten trees were used for each fertilizer treatment.

Pressure tests and storage studies were conducted in 1928, 1929, and 1930 on fruits from certain plots.

Investigations Conducted in 1928

When the studies on the firmness of flesh and

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*Soil Survey of Worcester County Maryland, by Bureau of Soils, U. S.D.A. in cooperation with Maryland Geological Survey and the Maryland Agricultural Experiment Station.

storage qualities were started, (1928), the trees receiving nitrogen were making ten to eleven inches terminal growth and were yielding six to eight bushels per tree, while the check trees were making only six to seven inches terminal growth and yielding only three to four bushels per tree.

Increase in trunk circumference was also somewhat greater for the fertilized trees than for the check trees (table 1).

A sample of one bushel was secured from each plot, taking a few fruits from each tree. Two lots of Williams were picked in 1928, on July 28, and July 31 respectively. These fruits were held in cold storage at Salisbury until October 1, 1928. Some fruit was held in an open barn at the prevailing temperatures.

Results. Both lots were pressure tested in the field, placed in cold storage, and again tested on August 3, and August 23. There were no consistent differences in the pressure tests among any of the fertilizer treatments, either at the time of picking or during storage.

The results of the July 28 picking are summarized in table 2. The rate of softening was quite rapid at first, but slowed up considerably after August 3. At this time, August 3, the fruit was in condition for commercial use. This fruit was left in cold storage until the first of October, but at that time it had softened beyond the prime eating condition, all plots testing around eight to ten pounds.

TABLE 1.

Total Growth of Trunk Circumference for Two Years, 1929-1930,

in Inches on the Various Fertilizer Experiments.

Orchard and Treatment	Growth	Orchard and Treatment	Growth
Harrison's Williams		Olney Stayman	
Sodium Nitrate	2.46 ± .183	Sodium Nitrate 16#	4.12 ± .36
Ammonium Sulphate	2.71 ± .101	Sodium Nitrate 8#	1.99 ± .084
No Nitrogen	1.98 ± .067	Check	.91 ± .011
Allen's Stayman		Tonoloway York	
Sodium Nitrate 20#	2.38 ± .092	Sodium Nitrate 20#	4.39 ± .017
Sodium Nitrate 10#	1.94 ± .082	Sodium Nitrate 20#	4.14 ± .128
Check	1.33 ± .102	Check	3.51 ± .208
Green Lane York		Walker's Elbertas	
Sodium Nitrate 20#	1.84 ± .054	Sodium Nitrate 10#	1.59 ± .014
Sodium Nitrate 10#	1.41 ± .081	Sodium Nitrate 5#	1.54 ± .012
Check	1.19 ± .078	Check	1.48 ± .020

TABLE 2

Firmness of Williams Apples, 1928, at Picking Time and During Storage as Affected by Fertilizer Treatments. (Pressure Tested in Pounds with Magness and Taylor Tester Using 7/16" Plunger.)

Date	Fertilizer Treatment				Storage Treatment
	$NaNO_3$	Check	$(NH_4)_2SO_4$	$NaNO_3$-P	
July 28	18.03	18.60	19.75	19.45	Cold storage
Aug. 3	15.94±.186	16.30±.165	17.23±.191	15.52±.194	Cold storage
Aug. 23	15.75±.422	15.90±.374	17.05±.250	17.13±.312	Cold storage
Aug. 2	8.13±.187	9.40±.185	10.27±.224	9.30±.184	Common storage
Aug. 4	7.07±.117	6.73±.074	7.78±.166	6.83±.096	Common storage

TABLE 3

Firmness of Williams Apples, 1929, at Picking Time and During Common Storage as Affected by Fertilizer Treatments. (Pressure Tested in Pounds with Magness and Taylor Tester Using 7/16" Plunger.)

Date	Fertilizer Treatment				
	$NaNO_3$	$(NH_4)_2SO_4$	$NaNO_3$-P	No Nitrogen	
July 15	20.6	20.6	21.4	21.1	
July 22	13.9±.68	14.0±.29	15.0±.44	14.3±.61	

The fruit picked July 31 ripened at about the same time as the fruit picked July 28. There were no differences in the firmness of fruit from the nitrogen and check plots.

Since most of the Williams crop is not held in cold storage, samples also were held under prevailing temperatures in a well ventilated barn. The results obtained in this common storage (table 2) are somewhat more variable than those obtained in cold storage, the fruit from plots receiving nitrogen alone testing about 0.6 pounds higher at the end of the storage than the check fruit or the fruit from the nitrogen plus phosphorus plots. No scald developed on any of the fruit, and very little decay. Most of the decay was caused by injury to the fruit in handling.

Summary. The pressure test results, obtained with Williams apples in 1928 indicate that nitrogen or phosphorus fertilizers have not caussd a change in the firmness of the fruit at picking time or in the rate of softening in storage when compared with fruit from plots which received no fertilizer. Fruit from all the plots was free from scald and practically free from decay.

Investigations Conducted in 1929

There was a very light crop of fruit in this orchard in 1929. For this reason only one picking could be made.

A one bushel sample of fruit was secured from

each plot, taking a few fruits from each tree. Only common storage studies were made in 1929. For this purpose a well ventilated barn was used, the fruit being examined each day.

Results. The results are summarized in table 3. As in 1928, the differences in the pressure test of the fruit from the different plots are too small to be considered significant. At picking time the fruit from the no nitrogen plot tested 0.5 of a pound more than the fruit from the sodium nitrate plot or the ammonium sulfate plot. At the end of the storage period the difference between the test of the fruits from these plots was 0.3 of a pound, which cannot be considered significant.

Summary. No significant differences appeared in the firmness of the flesh of Williams apples from different fertilizer plots in 1929, either at picking time or at any time during storage. There were practically no rots and no scald on the fruit from any of the plots.

Investigations Conducted in 1930

A heavy crop of fruit was borne on the trees in the Williams orchard in 1930. However, much of it was picked before it was mature. As a result the sample was taken from the second picking and only one sample was secured.

A one bushel sample was secured from each plot taking a few fruits from each tree. This sample was taken on July 21, and held in common storage until July 27.

TABLE 4

Firmness of Williams Apples, 1930, at Picking Time and Common Storage, as Affected by Fertilizer Treatment.

(Pressure Test in Pounds With Magness and Taylor Tester, 7/16 Inch Plunger).

Treatment	July 21	July 22	July 24	July 26	July 27
$NaNO_3$	18.05	15.12	13.52	8.83	8.47
$(NH_4)_2 SO_4$	18.61	18.52	13.16	10.30	9.85
Check	19.47	16.92	13.98	10.30	8.76

Results. Fruit from all plots softened at about the same rate (table 4). The softening was slightly faster at the beginning than at the end of storage. There is a tendency for the fruit from the plot receiving sodium nitrate to be slightly softer at picking time than fruits from the check plot. However, this tendency did not persist throughout the entire storage period, the difference being 1.42 pounds at picking time but only 0.29 pounds on July 27. Since this difference was not found in the results of the two previous years it is of doubtful importance.

Summary. For the season of 1930, no consistent differences were present in the firmness of the Williams fruit from the sodium nitrate or ammonium sulfate plots as compared with the firmness of fruit from the check plot. At the beginning of storage the fruit from the sodium nitrate

plot was a little softer, but by the end of the storage period there was practically no difference (.29 lb).

Summary of Results Obtained With Williams

Studies of the effects of nitrogen on the keeping quality of Williams apples have been made during three fruiting seasons -- 1928, 1929, and 1930. The samples of fruit obtained from this orchard, while not large, have consisted of uniform fruit. During this study no correlation has been found between fertilizer applications, including sodium nitrate, ammonium sulfate and acid phosphate, and the keeping quality of the fruit.

STAYMAN APPLES, OLNEY, MARYLAND.

This Stayman orchard is about seventeen miles northwest of College Park, in Montgomery County, Maryland. The land slopes gently to the east.

In 1926, whenthe fertilizer experiment was started, the trees in this orchard were sixteen years old and were in a devitalized, nitrogen-deficient condition. The soil was a Chester loam* and a system of sod mulch had been practiced. All trees were given a moderately heavy pruning in 1926.

The plots were divided into three groups, one of which received the fertilizer in the spring about three weeks before blossoming, one received the fertilizer in the

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*Soil Survey of Montgomery County Maryland by the Bureau of Soils, U.S.D.A. in cooperation with Maryland Geological Survey and Maryland Agricultural Experiment Station.

fall, and one group received half of its fertilizer in the spring and half in the fall. Fertilizers were applied under the spread of the limbs. Nitrogen was applied in two amounts on the basis of eight and sixteen pounds of sodium nitrate per tree, and was applied in the form of sodium nitrate, ammonium sulfate, calcium nitrate, urea, calurea, and leuna salpeter.

Growth response to the application of nitrogenous fertilizer was very marked. The fertilized trees increased from two to four times as much in trunk circumference as the check trees (table 1). The increased growth of these trees was nearly in proportion to the amount of nitrogen applied. Increased growth of the top was also very marked as indicated by figures 1 and 2.

Pressure tests and storage studies were made in 1928 and 1930 but no work was done in 1929, due to a very small crop on the trees. Chemical and respiration studies were conducted in 1930.

Investigations Conducted in 1928

In 1928, the differences in growth response of the nitrated trees and check trees was very marked. This difference in growth was reflected in the yield and condition of the fruit. Check plots were yielding about three bushels of fruit per tree, while the nitrogen plots were yielding nine to ten bushels per tree. The fruit on the check trees was smaller and more highly colored than the

TABLE 5.

Firmness of Stayman Apples at Olney, 1928, at Picking Time and During Storage.

Picked October 2, — Stored at 36 - 40° F.

(Pressure Test in Pounds with Magness and Taylor Tester, Using 7/16 inch Plunger)

Fertilizer Treatment	Oct. 3, 1928	Nov. 17, 1928	Jan. 14, 1928	Feb. 22, 1929	Total Decrease in Firmness
Sodium Nitrate)	16.31 ± .119	14.55 ± .110	9.73 ± .095	9.53 ± .045	6.78
Leuna Salpeter)	17.22 ± .176	14.36 ± .227	9.23 ± .055	9.26 ± .071	7.96
Urea) - Fall	15.72 ± .095	14.08 ± .106	9.35 ± .077	9.76 ± .158	5.96
Calcium Nitrate)	15.66 ± .135	14.10 ± .110	8.89 ± .071	9.27 ± .089	6.39
Ammonium Sulphate)	15.22 ± .115	13.88 ± .138	9.47 ± .071	9.15 ± .089	6.17
Check)	17.40 ± .219	15.67 ± .119	9.57 ± .084	9.77 ± .031	7.63
Leuna Salpeter)	15.50 ± .114	14.27 ± .090	10.12 ± .152	10.01 ± .089	5.49
Calcium Nitrate)	15.64 ± .174	13.75 ± .106	8.90 ± .077	9.07 ± .045	6.57
Sodium Nitrate) - Spring	15.97 ± .203	14.10 ± .106	10.21 ± .100	9.45 ± .055	6.52
Ammonium Sulphate)	15.02 ± .135	13.66 ± .110	9.55 ± .114	9.94 ± .063	5.08
Check)	17.43 ± .183	14.46 ± .100	8.88 ± .063	9.42 ± .031	8.01
Sodium Nitrate)	14.93 ± .209	13.77 ± .121	10.52 ± .077	10.23 ± .114	4.70
Ammonium Sulphate)	15.02 ± .153	14.13 ± .118	9.85 ± .118	9.52 ± .114	5.50
Calcium Nitrate) - Spring*	15.43 ± .124	13.90 ± .078	9.46 ± .148	9.25 ± .063	6.18
Leuna Salpeter)	16.02 ± .286	13.88 ± .137	11.48 ± .055	10.02 ± .089	6.00
Check)	18.41 ± .276	16.55 ± .156	9.92 ± .071	10.37 ± .071	8.04

*Double Applications.

Figure 1.

Stayman apple tree which has received sixteen pounds of sodium nitrate per year since 1926. Compare with figure 2.

Figure 2.

Stayman apple tree which has received no fertilizer since 1925. Compare with figure 1.

fruit on the nitrogen trees.

Pressure Tests and Storage Studies.

A one-bushel sample was secured from each plot, taking a few fruits from each tree. The samples were placed in the College cold storage (40°F) and pressure tests were made at intervals of about one month until the fruit was soft ripe, February 22.

Results. The fruit from the check trees tested significantly higher at the time of picking than fruit from any of the fertilized plots (table 5). These fruits were somewhat smaller and more highly colored than the fruits from the other plots. (The devitalized condition of the check trees made it impossible to get fruit from these trees which was exactly comparable to the fruit from the nitrogen plots).

After six weeks in storage, the differences in pressure test were still apparent but less significant, and by the end of the storage, February 22, had largely disappeared.

Of especial interest in connection with table 5 are the differences between the first and last pressure tests. These differences are shown in the last column of the table. Although there is no appreciable difference in the pressure test of the fruit from the different plots, at the end of the storage season, yet there is a difference in the actual amount which the fruits have softened in storage. The average decrease in pressure test of the fruit from the

check plots during storage is from two to three pounds greater than the average decrease in pressure test of the fruit from any nitrogen plots. The fruit from the plot receiving leuna salpeter in the fall is the only fruit from a fertilized plot which shows as great a rate of softening as the average of the check. But when the average test of the fruit from all plots receiving this treatment is compared with the average test for the fruit from the check plot, the rate of softening of the fruit from the check plots is seen to be greater. The amount of both scald and decay was very small and was not correlated with fertilizer treatment.

Summary. The application of nitrogen fertilizers to Stayman trees in 1929 has resulted in a less rapid rate of softening of the fruit in storage, though the check fruit was significantly firmer at picking time, no differences were evident at the end of storage.

Investigations Conducted in 1930

No fertilizer was applied to any of the plots in 1930, either in the spring or fall. In spite of this, there was still a marked difference in the general appearance of the check trees as compared with the nitrogen trees. For this reason, samples were secured from some of these plots in the fall of 1930. Fruit was taken from two plots in 1930, one of which received sixteen pounds of nitrate of soda in the spring of 1929, while the other plot was a nearby check.

In spite of the exceptionally dry growing season of 1930, the trees in this orchard had a uniformly heavy crop of good size fruit (2-1/2 - 3-1/4 inches). This was particularly good in comparison with other sod orchards in the state which were not irrigated in 1930. However, few blossom buds were formed in 1930 and a light bloom resulted in 1931, except on some check trees which bore small crops in 1930. The fruit was more uniform than in 1928, though again the fruit from the check plot was more highly colored than the fruit from the fertilized plots (figure 3) and was slightly smaller. It was possible, however, to obtain fruit of about the same size from all plots for samples.

Pressure Tests and Storage Studies.

A four bushel sample was taken from the check plot and a similar sample from the plot which received sixteen pounds of sodium nitrate per tree. Two bushels were used for respiration studies and two for pressure testing and chemical studies. The fruit was held in storage at 32°F., a sample being removed for pressure testing and chemical analysis at the time of picking and again on November 7, January 6, and February 7.

Results. The pressure test data are presented in table 6. A very striking characteristic of the data in table 6 is its similarity to the results shown in table 5.

As in 1928, the fruit from the check plot tested somewhat higher at the beginning and lower at the end of the

TABLE 6.

Firmness of Stayman Apples at Bowdler's, 1930, at Picking Time and During Storage.

Picked October 6 — Stored at 32° F.

(Pressure Test in Pounds with Magness and Taylor Tester Using 7/16 inch Plunger)

Plot		Fertilizer Treatment	Oct. 6, 1930	Nov. 7, 1930	Jan. 6, 1931	Feb. 7, 1931	Total Decrease in Firmness
52	#1	$NaNO_3$ Double	16.76 ±.054	15.06 ±.037	13.68 ±.091	11.91 ±.075	
	#2	" "	16.58 ±.094	15.33 ±.060	*		
	#3	" "	16.20 ±.070	14.98 ±.060	14.04 ±.078	12.03 ±.094	4.54
57	#1	Check	17.07 ±.077	15.08 ±.060	*		
	#2	"	17.79 ±.105	14.74 ±.059	11.33 ±.070	11.00 ±.152	
	#3	"	17.82 ±.089	14.94 ±.050	11.38 ±.087	11.17 ±.061	6.14

*Removed for Respiration Studies.

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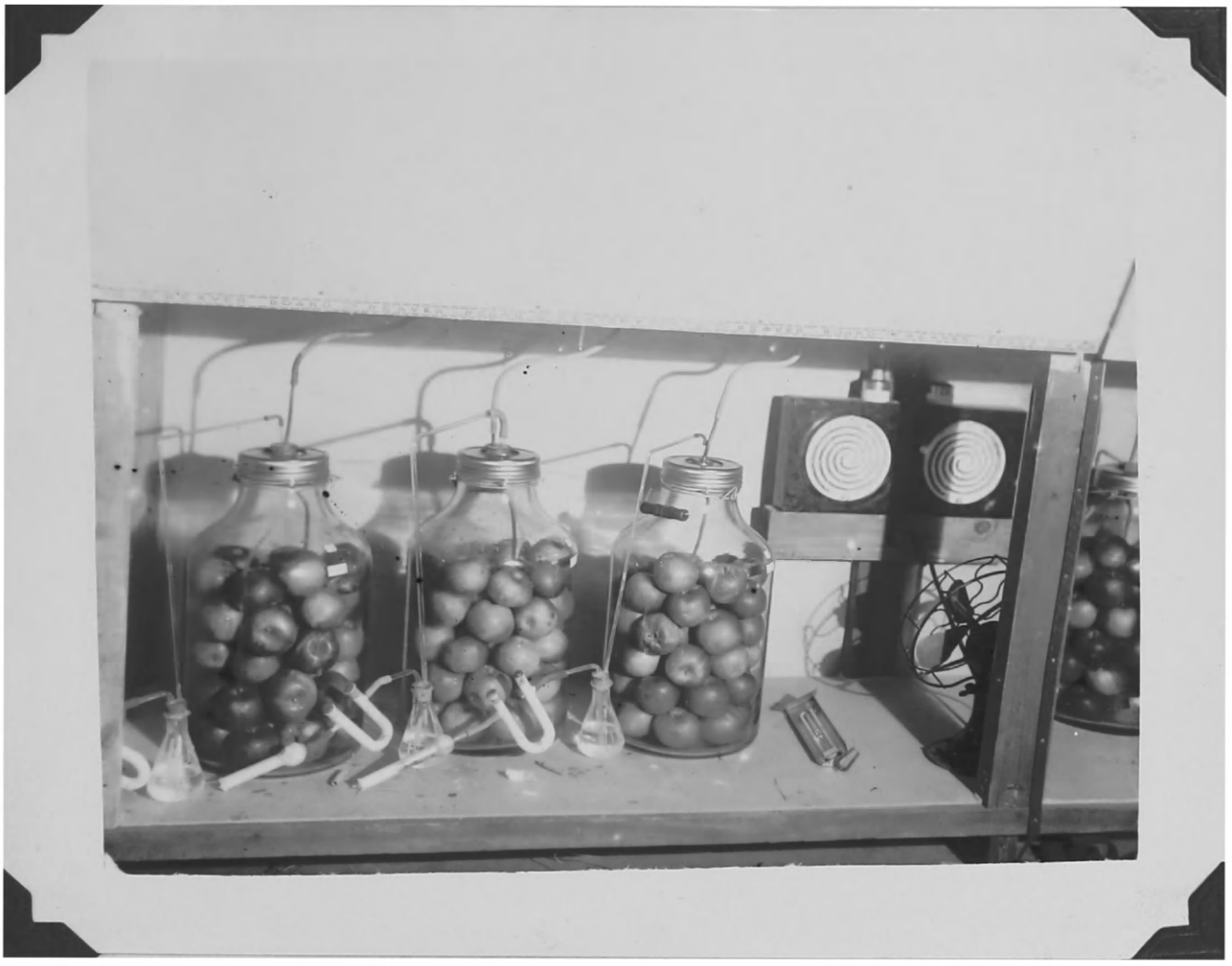

Figure 3

Section of respiration apparatus. Fruit in the first jar (left to right) is from the check plot of the Stayman orchard at Olney, while fruit in the third jar is from the plot which received sixteen pounds of sodium nitrate per tree. Note the difference in color.

storage period than the fruit from plots which received nitrogen. The last column of table 6 shows the average differences between the first and last pressure tests. It is plainly evident that the fruit from the nitrogen plots has softened less in storage than fruit from the check plot. Practically no scald or decay developed on any of the fruits, and no correlation was found between nitrogen applications and scald or decay in storage.

Summary. The application of sixteen pounds of sodium nitrate to Stayman trees in 1929 has resulted in a decreased rate of softening compared to that of the fruit from the check plot in 1930. The fruit from the check plot was firmer at picking time but no differences were evident at the end of storage. Nitrogen had no influence on the amount of scald or decay of the fruit in storage.

Chemical Studies.

Samples for chemical analysis were taken when the fruit was picked, October 6, 1930, and again on November 25, January 6, and February 7 from fruit from the plot receiving sixteen pounds of sodium nitrate per tree and from the check plot. An endeavor was made to correlate chemical composition and chemical changes of the fruit during storage with keeping quality as measured by mechanical means.

The tissue was analyzed for reducing sugars, total sugars, starch, alcohol-insoluble-acid hydrolyzable substances, sucrose, (by difference), and total nitrogen.

Ph and total acidity were also determined. Nitrogen determinations were made only on samples taken November 25.

Separate samples were taken at each of the above mentioned dates for the study of pectin constituents. Since pectin changes are correlated with softening of the flesh of apples as shown by Haller (13-a) an attempt was made to use these changes as a measure of the ripening process. The fruits were analyzed for soluble and total pectic materials, the insoluble material being determined by difference. Detailed methods of chemical analysis are given in the appendix.

Results. The results of the chemical studies are summarized in table 7. The results shown in table 7 indicate that the application of nitrate of soda to the soil has caused a consistent increase in the reducing sugar content of the fruit. These results are in accord with those obtained by Hopkins and Gourley (16) who show that increases in the quantity of nitrogen applied to Stayman apple trees resulted in a slightly higher sugar content of the fruit. No analyses were shown for fruit from check plots. However, they make the following statement. "The conclusion would seem warranted from the results thus far that the application of nitrates has little effect on the soluble carbohydrate content of apples. Wallace (37) has also shown an increase in the sucrose content with applications of nitrogen with certain rootstocks.

TABLE 8.

Respiration Results on Stayman.

Respiration Rate of Check Expressed as 100.

Plot and Treatment	December						
	22	23	24	25	26	27	28
57 Check	100	100	100	100	100	100	100
52 Double Nitrogen	106.2	102.6	105.8	105.3	102.5	102.2	97.6

	January								
	1	2	3	5	7	8	9	10	12
57 Check	100	100	100	100	100	100	100	100	100
52 Double Nitrogen	105.2	102.5	108.8	109.5	100.1	104.2	102.6	105.5	103.5

The nitrogen content of the fertilizer plots was 23.07 per cent greater than the nitrogen content of the fruit from the check plot. Gourley and Hopkins (13) report increases as great as 100 per cent while Lagasse found an increase of 18.7 per cent between fruit from nitrated and check plots. The dry weights are not correlated with nitrogen applications or nitrogen content. When the total carbohydrates are calculated on a fresh weight basis it seems that there is no correlation between nitrogen content and total carbohydrates.

Both the total sugar and reducing sugar content in fruit from both plots increased until January 6, after which there was a falling off with both.

By January 6, practically all the starch had disappeared, which no doubt, accounts for the fact that sugar content after January 6 was no longer increasing. Following January 6, the respirational activity of the fruit caused a decrease in the sugar content.

Fletcher (12) reports that increases in the amount of red color on apples is associated with an increase in the reducing sugar content. That the red color development was greater on the fruit from the check plot is shown in figure 3. Yet the fruit from this plot had less reducing sugars than did fruit from the nitrate plot. This same condition existed with the York apples from the Green Lane orchards as will be brought out later. Light, also

associated with color formation by Fletcher (12) was possibly the factor which caused differences between check fruit and fertilized fruits, since the check trees had sparse foliage.

The Ph and total acidity were determined at each sampling date (table 7). No significant differences were noted, between treatments regarding either Ph or total acidity. Total acidity decreased as the season advanced, while there was little change in Ph. Gourley and Hopkins (13) report little difference in the Ph between fruit from fertilized and non-fertilized plots.

Summary Nitrogen applications to the soil have resulted in: (1) an increase in the nitrogen content of the flesh of the fruit, (2) an increase in the amount of total reducing sugars, (3) increased nitrogen content is associated with increased starch content early in the season. The application of nitrogen has caused these changes without a corresponding change in keeping quality of the fruit.

Respiration Studies

During the ripening process of apples the sugars are oxidized in the process of respiration with the subsequent liberation of carbon dioxide and water. Increased carbon dioxide liberation would indicate a greater rate of breaking down of sugars. For this reason respiration studies were made on the fruit from the nitrogen and check plots to see which was breaking down at the greater rate, and to correlate the results, if possible, with the results of studies on keeping quality.

A detailed description of the apparatus and methods used in the respiration studies is given in the appendix. A diagram of the apparatus is shown in figure 10.

Results. Figure 4 shows the respiration rates of the fruit from the check plot and from the plot which received sixteen pounds of nitrate of soda. The check is shown as one-hundred while a straight line of closest fit has been constructed for the respiration rate of the fruit from the plot receiving sixteen pounds of nitrate as compared to the rate of the check fruit. Kidd and West (17) found high nitrogen content to be associated with high rate of respiration. Gourley and Hopkins (13) on the other hand found no significant differences in the rate of respiration caused by increases in the nitrogen content of the fruit, even though these differences were as great as one-hundred per cent.

The results of the respiration studies assume greater significance when one considers that the results are based on two samples of fruit. The first sample scalded after about ten days and had to be replaced. Another bushel of fruit from each plot was taken from storage and placed in the respiration chambers, along with some shredded oiled paper. The relationship existing between the plots remained the same for the two plots in both sets of respiration data.

Data indicate that the rate of respiration is increased but slightly with increases in nitrogen content of the fruit.

TABLE 9

Firmness of Stayman Apples, Salisbury, 1928, at Picking Time and During Storage.

(Picked Oct. 2, Held in Cold Storage 32°)

(Pressure Tested in Pounds with Magness and Taylor Tester Using 7/16" Plunger)

	Plot Treatment	Oct. 3, 1928	Dec. 8, 1928	Feb. 1, 1929	Mar. 15, 1929	Total Decrease in Firmness
1	$(NH_4)_2SO_4$ double	17.17 ± .173	13.59 ± .105	12.11 ± .084	11.52 ± .078	5.65
2	$(NH_4)_2SO_4$ single	17.95 ± .109	14.47 ± .100	12.64 ± .089	12.24 ± .135	5.71
3	$(NH_4)_2SO_4$ Lime	18.42 ± .197	14.70 ± .134	12.37 ± .114	11.86 ± .100	6.56
4	Check	17.32 ± .127	14.00 ± .071	12.01 ± .071	10.40 ± .095	6.92
5	Nitrate Lime	18.66 ± .187	13.14 ± .114	12.40 ± .119	11.11 ± .145	7.55
6	$NaNO_3$ single	18.17 ± .187	13.94 ± .063	12.83 ± .107	11.67 ± .119	7.05
7	$NaNO_3$ double	17.62 ± .181	13.50 ± .078	12.12 ± .064	11.33 ± .089	6.29
12	$NaNO_3$ Aug. 1	17.80 ± .181	13.59 ± .130	12.71 ± .110	11.98 ± .145	5.82
13	Check	17.66 ± .130	14.42 ± .109	12.23 ± .105	11.81 ± .089	5.85
14	N-P-K	17.02 ± .161	12.42 ± .105	10.86 ± .089	10.70 ± .105	6.32
17	$NaNO_3$ Sept. 1	17.11 ± .109	13.25 ± .063	11.76 ± .084	10.58 ± .089	6.53
18	Acid Phosphate	17.06 ± .200	12.48 ± .055	11.42 ± .100	10.67 ± .078	6.39
19	Muriate of Potash	17.02 ± .158	12.40 ± .071	11.13 ± .175	10.34 ± .078	6.68
20	Acid Phosphate KCl	16.60 ± .114	13.98 ± .044	11.35 ± .084	10.46 ± .044	6.14
21	$NaNO_3$ Acid Phos.	16.09 ± .105	13.81 ± .095	11.55 ± .078	11.34 ± .084	4.79

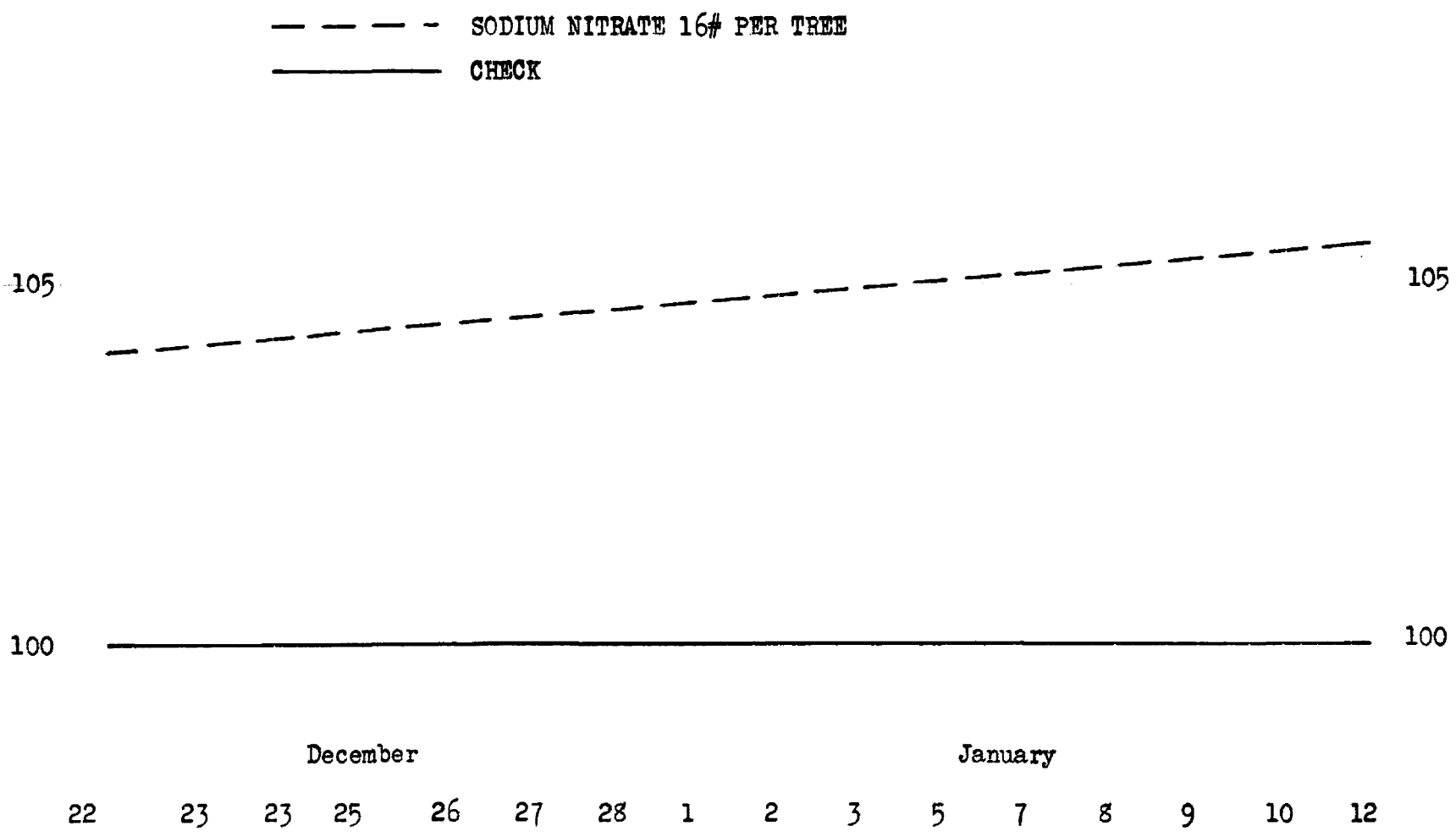

Figure 4.

Respiration rate of the fruit from the Stayman trees which received sixteen pounds of sodium nitrate, as compared to the respiration rate of the fruit from the check trees as 100.

Summary of 1930 Results

Nitrogen applications on Stayman apple trees has caused the fruit to be softer at picking time and has resulted in a decrease in the rate of softening of the fruit in storage since at the end of storage there was no difference in firmness between treatments. Nitrogen applications also resulted in an increase in total nitrogen content of the flesh, an increase in sugar content and a slight increase in the rate of respiration, which, apparently cannot be correlated with the results on keeping quality.

General Summary of Results Obtained With Stayman Apples at Olney, Maryland

This investigation covering two years indicates that nitrogen fertilizers on Stayman apple trees have decreased the firmness of the fruit at picking time though no differences were evident at the end of storage, thus, the rate of softening of the fruit in storage, was increased, although fruits from the check trees were firmer at the time of picking. Nitrogen fertilizers have also increased the total nitrogen content of the flesh of the fruit, increased the sugar content of the fruit and increased the rate of respiration, compared with fruit from trees receiving no nitrogen.

Although application of nitrogen fertilizers to the soil has resulted in a change in the chemical compo-

sition of the fruit, this change in the chemical compoistion has not been accompanied by a corresponding change in the keeping quality of the fruit.

STAYMAN APPLES AT SALISBURY, MARYLAND

Description of Orchard and Plots. This orchard was owned by the W. F. Allen Orchard Company of Salisbury, in Wicomico County, Maryland, and was located on a level Sassafras loamy sand.* The trees were thirteen years old when the fertilizer treatments were started in 1922, so that the plots used for the studies had been receiving the different fertilizer treatments for five years prior to the beginning of the studies on the firmness of flesh and storage qualities of fruit. A system of clean cultivation and cover crops was employed.

Ten trees were used for each fertilizer treatment. Certain plots received ten pounds and others twenty pounds of sodium nitrate per tree, while others received the equivalent of these quantities of nitrogen in the form of ammonium sulfate. Phosphorus and potassium were applied to some plots, in addition to the ten pounds of nitrogen, at the rate of ten pounds of acid phosfate or five pounds of muriate of potash or both, per tree. All the fertilizer was applied under the spread of the limbs, about three weeks before blossoming.

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*Soil Survey of Wicomico County, Maryland by the Bureau of soils, U.S.D.A. in cooperation with the Maryland Geological Survey and Maryland Agricultural Experiment Station.

Investigations Conducted in 1928

The check trees in this orchard were smaller and were making less growth than the fertilized trees (table 1). The difference in appearance of the trees is visible in figures 5 and 6. The fruit from these plots was fairly large in 1928 and many cracked fruits were present on all plots.

Pressure Tests and Storage Studies.

A one-bushel sample of fruit was secured from each plot by taking a few fruits from each tree. The samples were held in cold storage (32°F.) and pressure tested at intervals of about four weeks until March 15, 1929.

Results. Pressure tests at the time of picking and subsequent tests at intervals during the storage period, October 2 to March 15, revealed no significant differences among samples from any of the plots. The greatest differences at this time were about one pound (table 9). The fruit showed the same firmness and rate of softening whether taken from unfertilized plots or from plots receiving ten or twenty pounds of sodium nitrate per tree, or nitrate plus acid phosphate or a complete fertilizer.

This Stayman orchard, while about the same age as the one at Olney, Maryland, had received better care as regards pruning and soil management. The difference in vigor between the check trees and the fertilized trees was much less in this orchard than in the Olney orchard. More uniform samples were obtained and this uniformity is reflected

TABLE 10.

Firmness of Stayman at Allen's, 1929, at Picking Time and During Storage.

(Pressure Test in Pounds Using Magness and Taylor Tester with 7/16 inch Plunger.)

Fertilizer Treatment	Sept. 28,1929	Nov. 2,1929	Dec.14,1929	Jan.18,1930	Feb.15,1930	Mar.17,1930	Total Decrease in Firmness.
1 $(NH_4)_2SO_4$ double	16.97	16.20	13.87	11.70	12.34	9.93	7.04
2 " single	17.01	17.05	14.90	12.71	12.71	10.07	6.94
4 Check	17.19	16.40	14.59	12.61	12.87	10.23	6.96
6 $NaNO_3$ single	16.32	15.91	13.32	12.23	12.36	10.04	6.28
7 " double	16.92	15.95	14.30	12.55	12.05	10.64	6.28

Figure 5.

Stayman apple tree which has received no fertilizer since 1921. Compare with figure 6.

Figure 6.

Stayman apple tree which has received twenty pounds of sodium nitrate each spring since 1922. Compare with figure 5.

in the pressure test results. No differences were evident at picking time as was the case with the fruit from the Olney orchard, where check fruit was firmer. Furthermore, there was no apparent difference in the rate of softening.

Summary. Nitrogen fertilizers on Stayman apples had no effect on the firmness of the flesh of the fruit at picking time or on the rate of softening of the fruit in storage. No internal breakdown, scald or decay appeared in fruits from any of the plots, even though there was much cracked fruit in the orchard at picking time.

Investigations Conducted in 1929

There was a light crop on all plots in 1929 and the fruit was exceptionally large, much of it being cracked. The samples consisted of about three inch fruit.

Pressure Test Studies

In 1929 duplicate samples of one bushel each were picked on September 28 and placed in cold storage. These fruits were pressure tested at subsequent intervals of about one month until March 17.

Results. These results are summarized in table 10. As in 1928, no significant differences were apparent in the pressure tests of the fruit. The pressure tests and the rate of softening were approximately the same regardless of the fertilizer treatment. The greatest difference being about 0.4 pound. No scald or internal breakdown was present on this fruit even though the fruit was

TABLE 15.

Tonoloway, York, 1929.

Treatment		Pressure test in pounds using the Magness and Taylor tester with the 7/16 inch plunger. Oct.6	Nov.8	Dec.6	Jan.10	Feb.22	Percentage of sound fruit based on the original number of fruits in each basket. Dec.6	Feb.22	Mar.29	% Scald Mar.29
$NaNO_3$ 20#	1:	20.98	19.77	18.15	18.37	15.30	100	95.80	82.60	14.78
"	2:	21.64	19.53	19.34	18.74	15.93				
" 15#	1:	21.35	20.80	19.52	19.42	15.97	100	98.50	91.86	8.14
"	2:	21.80	19.54	19.82	18.54	15.85				
" 8#	1:	22.70	20.46	19.60	18.71	16.05	100	93.60	96.58	3.42
	2:	21.18	19.79	20.02	18.75	15.62				
Check	1:	23.00	20.44	20.18	19.42	16.76	100	97.92		
	2:	22.70	21.40	19.71	19.87	17.66				

exceptionally large.

Summary. The differences in firmness of the flesh of the Stayman apples in 1929 from the different plots were not significant at picking time or at any time during the storage period. Even though the fruit was large, no storage disorders such as scald, decay, or breakdown were present on any of the fruits.

Investigations Conducted in 1930.

There was a light crop on all these plots in 1930 and because of the dry season the fruits were only medium sized (2-3/4 inches).

Pressure Tests and Storage Studies

On September 30, 1930 a sample was taken from the same plots which were used in 1929. Pressure tests were made at picking time and at intervals during storage at 32°F. The results are tabulated in table 11. In 1930 the samples consisted of three bushels of fruit from each plot. All three bushels were used for pressure test and storage studies.

Results. A study of table 11 reveals no significant differences in the pressure test of the fruit from any of the plots at picking time or at any time during the storage period, the differences being less than a pound in most cases. The fruit was inspected on January 26, and March 2, for sound, scalded and decayed fruits. There

TABLE 11.

Firmness of Stayman at Allen's, 1930.

(Pressure Test in Pounds Using Magness and Taylor Tester with 7/16 inch Plunger.)

Fertilizer Treatment.	Basket No.	Sept.30,1930	Nov.10,1930	Dec.14,1930	Jan.26,1931	Mar.2,1931	Jan.26,1931 % Sound	Mar. 2, 1931 % Sound
$(NH_4)_2SO_4$ 15#	1	19.67 ± .138	17.85 ± .105	15.67 ± .125	13.68 ± .173	12.54 ± .096	93.44	29.50
"	2	18.62 ± .132	17.65 ± .081	15.52 ± .162	12.68 ± .094	12.24 ± .102	79.24	24.52
"	3	19.61 ± .163	17.56 ± .108	15.82 ± .124	13.45 ± .091	13.07 ± .125	90.75	33.33
$(NH_4)_2SO_4$ 7½#	1	19.70 ± .107	17.63 ± .105	16.57 ± .120	13.54 ± .115	12.93 ± .108	98.27	56.89
"	2	19.55 ± .201	18.02 ± .157	15.40 ± .076	13.72 ± .097	12.74 ± .093	87.66	30.00
"	3	19.07 ± .116	17.76 ± .120	15.40 ± .133	13.01 ± .086	13.30 ± .086	93.34	46.66
Check	1		17.78 ± .126	15.92 ± .143	13.71 ± .172	13.86 ± .139	93.93	54.54
"	2	18.90 ± .122	17.16 ± .089	16.05 ± .164	13.25 ± .090	12.82 ± .139	90.75	51.85
"	3	19.03 ± .128	18.37 ± .127	16.31 ± .140	13.35 ± .123	12.56 ± .070	96.42	48.21
$NaNO_3$ 10#	1		18.77 ± .116	16.88 ± .145	14.01 ± .102	13.87 ± .168	96.82	71.42
"	2	20.34 ± .102	19.53 ± .195	15.54 ± .100	13.14 ± .085	13.38 ± .115	93.47	39.13
$NaNO_3$ 20#	1		17.57 ± .113	16.48 ± .117	13.13 ± .117	12.81 ± .115	79.73	44.59
"	2	19.48 ± .105	17.71 ± .110	15.40 ± .129	13.48 ± .158	12.86 ± .107	94.55	43.63
"	3	18.67 ± .112	18.28 ± .123	16.30 ± .085	12.71 ± .114	13.35 ± .119	89.09	40.00

were practically no decayed fruits, so only the scalded and sound fruits are considered here. The percentages of these for the respective dates are shown in the last two columns of table 11. The results are quite variable, especially on the later date. These figures are not consistent enough to warrent any definite conclusions. They would indicate, however, that the fertilizer treatments had had little effect on the storage quality of the fruits as indicated by storage counts.

Summary. Fertilizer applications on Stayman apples in 1930 resulted in very little change in the rate of softening or in the firmness of the fruit, and caused no consistent differences in the amount of scald.

Summary of Results Obtained With Stayman Apples at Salisbury

Pressure test results over a period of three years indicate that nitrogen applications to Stayman apple trees have had no influence on the firmness of the flesh at picking time or on the rate of softening of the fruit in storage. Inspections of the fruit in storage, have revealed no consistent differences in the amount of scald or decay as a result of the application of nitrogenous fertilizers.

YORK IMPERIAL APPLES, TONOLOWAY, HANCOCK, MARYLAND

Description of Orchard and Plots. This orchard

is owned by the American Fruit Growers, and is located on the east slope of a steep ridge, west of Hancock, in Washington County, Maryland. The soil is classified as Hagerstown clay loam.* The trees were about twenty-five years old and a system of sod culture had been employed. Heavier pruning, fertilization and cultivation, prior to the starting of this study caused the trees in this orchard to be more vigorous than the trees at the Green Lane Orchard, described later. The trees were planted 33 x 40 feet and forty-five trees were used for each treatment. However, for this particular study, only the first twenty-five trees from the base of the slope were used. The relative growth made by the fertilized and check trees is shown in table 1 and figures 7 and 8.

Some nitrogen plots received eight pounds of sodium nitrate per tree or the equivalent of this quantity of nitrogen in the form of various other carriers of nitrogen, including calcium nitrate, urea, leuna salpeter and calurea. In addition, some plots received ten, fifteen and twenty pounds of sodium nitrate per tree. Some trees received the full application of hitrogen in the spring about three weeks before blossoming; some received the full amount in the fall, while others received half of the fertilizer in the spring and half in the fall.

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*Soil Survey of Washington County, Maryland by Bureau of Soils, U.S.D.A. in cooperation with the Maryland Geological Survey and Maryland Agricultural Experiment Station.

Figure 7.

York apple tree which has received no fertilizer since 1925. Compare with figure 8.

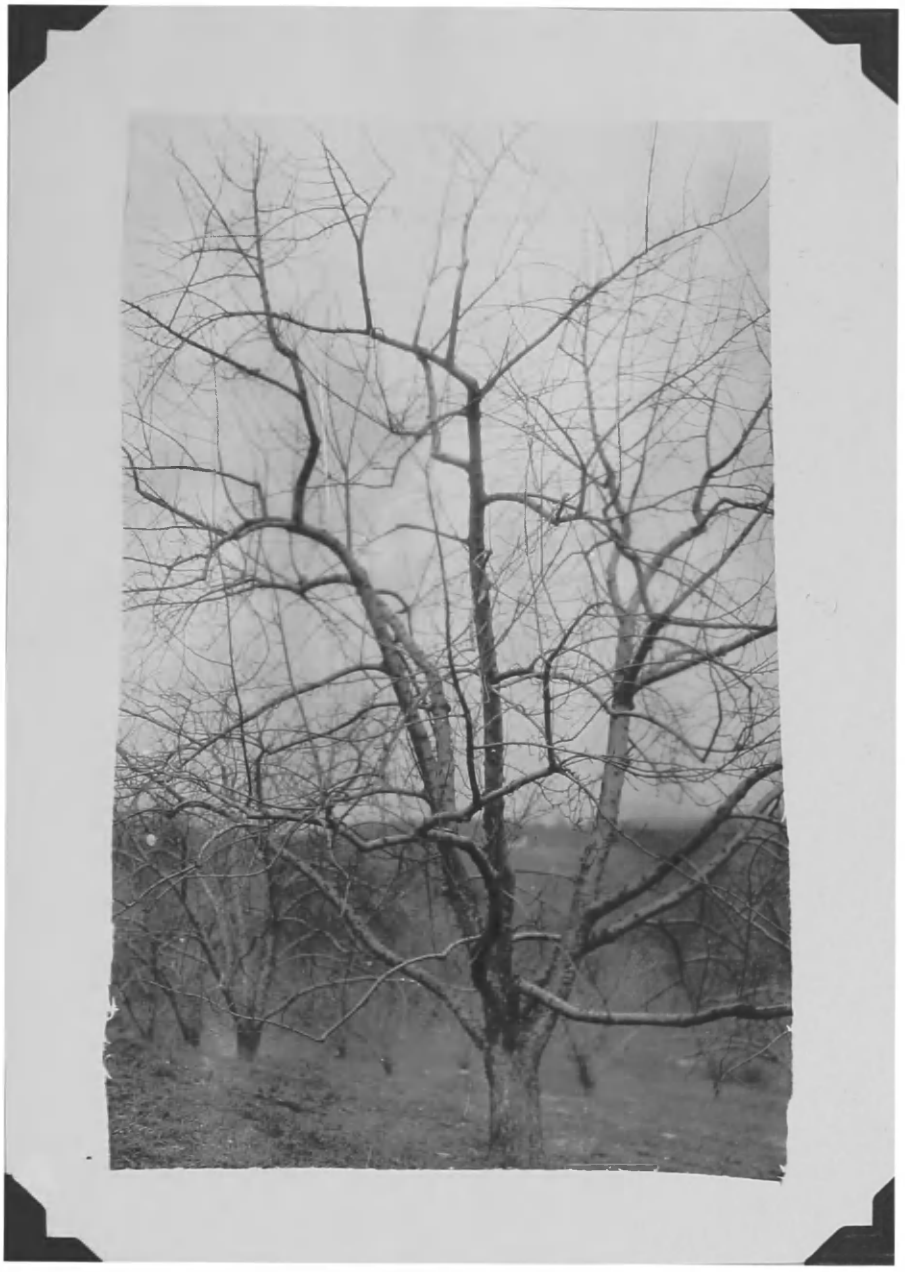

Figure 8.

York apple tree which has received twenty pounds of sodium nitrate per year since 1926. Compare with figure 7.

The experimental plots in this orchard were organized in 1926, the check trees have received no fertilizer since 1925.

Investigations Conducted in 1927

In 1927 no differences were evident in the appearance of the trees or the fruit from the nitrogen and check plots. The trees from the check and nitrogen plot had about the same crop.

Pressure Test and Storage Studies

In 1927 fruit from the spring treated sodium nitrated plots and check plot was held in both cold and common storage. The fruit from each plot was divided into three lots of one barrel each, according to size, namely 2-1/4, 2-1/2, and 3 inch. The fruit was selected from the orchard crates after the regular pickers had harvested the fruit.

Results. Pressure tests at the time of picking and again December 14, January 19, March 1, and April 1, revealed practically no differences in keeping quality or firmness of flesh among any of the samples. Differences were usually less than a pound when the firmness of check and nitrated fruit was compared. In both cold and common storage, the fruit from plots receiving fifteen and twenty pounds of nitrate of soda per tree, the largest amounts of nitrogen applied, and the fruits from the check plots,

showed about the same degree of firmness at the end of the season. The results are shown in table 12. No consistent differences in the amount of decay or scald were evident between fruits from the sodium nitrate and check plots.

Summary. Nitrogen fertilizer applications resulted in no marked changes in the rate of softening, or in the firmness of the flesh of York Imperial apples from the check plot as compared with fruits from the nitrated plots, in 1927. Fruits of one size from the check plot were compared with similar sized fruit from the nitrogen plots.

Investigations Conducted in 1928

In 1928 the check trees were showing the need of nitrogen by a reduced growth and a lighter green shade of leaves.

Pressure Test and Storage Studies

On October 11, 1928 a one bushel sample of fruit was again taken from these plots and held in cold storage, (32°F). until April 6, 1929.

Results. The results of the pressure tests are shown in table 13. At picking time the fruits from all plots showed about the same resistance to pressure. At the end of the storage season, however, fruit from the check plot tested from one to two pounds higher than fruits from plots receiving nitrogen. Fruit from one of the calurea plots tested about the same as the check, but fruit from the other tested lower. This is directly oppostite to

TABLE 12.

Firmness of York Apples, Tonoloway, 1927

(Pressure Test in Pounds Using Magness and Taylor Tester with 7/16 inch Plunger.)

Treatment	Size	Cold Storage			Common Storage	
		Oct.21,1927	Mar.5,1928	Apr.12,1928	Jan.11,1928	Feb.16,1928
$NaNO_3$ 20#	3 in. up	18.87	13.16	13.23		
" 15#	"	18.82	13.16	12.73		
" 10#	"	19.38				
" 8#	"	17.68	12.36	11.63		
Check	"	19.90	12.78	12.21		
$NaNO_3$ 20#	$2\frac{1}{2}$-3 in.	19.60	14.40	13.45	11.80	10.73
" 15#	"	21.45	12.32	11.58	14.02	12.13
" 10#	"	20.60	12.58	12.19	12.10	11.30
" 8#	"	19.13	12.94	12.48		
Check	"	20.10	13.70	12.38	12.02	11.30
$NaNO_3$ 20#	$2\frac{1}{4}$-$2\frac{1}{2}$ in.	22.53	14.84	13.95		
" 15#	"	22.40	14.34	13.29		
" 10#	"	23.10	13.86	12.98		
" 8#	"	21.93				
Check	"	22.02	14.67	13.88		
Ave. of $NaNO_3$	"	20.45	13.39	12.75		
Ave. of Check	"	20.80	13.72	12.82		

TABLE 13.

Firmness of York, Tonoloway, Hancock, Maryland, 1928.

Picked Oct. 11, Held in Cold Storage.

(Pressure Test in Pounds Using Magness and Taylor Tester with 7/16 inch Plunger.)

	Plot	Treatment	Tested Oct.11	Tested Dec.14	Tested Jan.19	Tested Mar. 1	Tested Apr. 6
1	8#	Na E	22.20 ± .187	18.67 ± .118	17.36 ± .205	17.08 ± .148	13.66 ± .053
2	8#	Na A	21.35 ± .301	20.20 ± .100	18.42 ± .259	17.00 ± .247	14.91 ± .117
3	2.6#	Calurea A	20.28 ± .274	19.20 ± .118	16.02 ± .123	17.72 ± .105	13.35 ± .050
4	4.6#	Leuna A	21.31 ± .261	17.76 ± .100	16.50 ± .110	15.44 ± .071	14.21 ± .038
5	8#	Ca A	18.71 ± .167	17.88 ± .123	16.21 ± .170	16.04 ± .161	14.32 ± .048
6	15#	Na A	20.10 ± .245	17.22 ± .164	15.80 ± .151	15.08 ± .134	15.41 ± .044
7	15#	Na B	19.99 ± .205	17.52 ± .105	16.00 ± .071	15.26 ± .118	13.80 ± .052
8		Check	21.20 ± .251	19.66 ± .110	18.48 ± .134	16.48 ± .161	16.38 ± .123
9	20#	Na A	21.62 ± .205	18.19 ± .105	17.30 ± .123	15.47 ± .123	14.20 ± .148
10	20#	Na B	21.03 ± .300	16.90 ± .187	16.42 ± .151	15.14 ± .158	14.65 ± .143
11	10#	Ca A	21.00 ± .158	17.76 ± .123	16.97 ± .134	16.20 ± .187	14.80 ± .121
12	5.7#	Leuna A	20.02 ± .219	17.02 ± .063	16.87 ± .095	16.02 ± .152	14.80 ± .079
13	3.3#	Calurea A	20.18 ± .224	17.10 ± .084	16.68 ± .164	16.80 ± .118	16.05 ± .125
14	10#	Na A	19.85 ± .300	18.98 ± .176	17.78 ± .167	16.95 ± .138	15.25 ± .053
15	3.3#	Urea E	21.20 ± .270	16.96 ± .110	17.00 ± .100	15.36 ± .134	13.36 ± .062
16	8#	Na	19.12 ± .205	17.88 ± .105	16.70 ± .134	15.39 ± .095	14.40 ± .102

A — Total application distributed as terminal buds are opening.

B — Partial application as terminal buds are opening balance after pink spray.

E — First application as terminal buds are opening balance about Sept. 1.

the results obtained with Stayman. With Stayman the rate of softening was slower for the fertilized fruit than for the fruit from the check plot, while with the York apples the rate of softening was somewhat greater for the fertilized than the check fruit.

The results of the storage counts onthese fruits are shown in table 14. No differences in the percentage

TABLE 14

York Apples, Tonoloway, 1928

Percentage of Sound Fruit Based on the Number of Fruits at the Beginning of the Storage Season.

Treatment	Number of Fruits	Dec. 14 % Sound	Jan. 19 % Sound	March 6 % Sound
1. 8# $NaNO_3$	118	93.24	77.11	8.47
2. 8# $NaNO_3$	118	96.62	82.20	9.75
3. 2.6 # Calurea	119	93.28	80.62	5.04
4. 4.6# Leuna	119	96.64	81.50	3.36
5. 8# Ca $(NO_3)_2$	123	95.14	82.90	10.57
6. 15# $NaNO_3$	128	93.76	79.62	7.03
7. 15# $NaNO_3$	123	95.14	82.15	9.15
8. Check	120	98.34	85.00	20.00
9. 20# $NaNO_3$	128	93.76	82.00	19.53
10. 20# $NaNO_3$	122	95.90	82.78	20.62
11. 10# Ca $(NO_3)_2$	123	98.38	80.05	13.82
12. 5.7# Leuna	119	92.44	79.00	5.88
13. 3.3# Calurea	121	97.52	85.15	17.35
14. 10# $NaNO_3$	112	99.11	85.65	8.06
15. 3.3# Urea	120	95.85	83.33	9.17
16. 8# $NaNO_3$	115	96.52	80.00	10.80

of sound fruits were evident until the last inspection. At this time, March 6, most of the fruit in all the plots had scalded. On the basis of the original number of fruits in each basket, the sample from the check plot had twenty per cent

of sound fruit and the samples from the plots receiving twenty pounds of sodium nitrate per tree averaged 20.07 per cent sound fruits, while the samples from the other nitrogen plots had less sound fruit as shown in table 14. The average per cent sound fruit in all the other nitrogen plots on March 6, was 9.11.

Summary. Nitrogen fertilizers have not caused a change in the firmness of York apples at picking time, though at the end of storage the fruit from the nitrated trees was about two pounds softer. Nitrogen had no definite effect on the amount of scald or breakdown in storage.

Investigations Conducted in 1929.

The differences in vigor between the nitrated and check trees were very evident in 1929, the check trees could be detected at a distance due to the lighter shade of green. Only the nitrate of soda plots were compared with the check in 1929 and 1930.

Pressure Test and Storage Studies.

Triplicate samples of one bushel each were obtained from these plots on October 6, 1929 and held at 32°F. until February 22. Two bushels were used for pressure test studies, while one bushel was kept for storage counts.

Results. The results of the pressure tests and storage counts are shown in table 15.

TABLE 16.

Tonoloway York 1930.

Firmness of Flesh as Measured by Magness and Taylor Tester using 7/16" Plunger.

Plot and Treatment	Basket	October 16	November 28	January 7	February 9	March 6	April 20	Percent Sound March 6	Percent Sound April 20	Percent Scald March 6	Percent Scald April 20
9. $NaNO_3$ 20#	1	22.23 ± .168	21.03 ± .236	18.87 ± .230	17.38 ± .124	17.12 ± .103	15.62 ± .135	95.87	49.48	4.13	32.99
" "	2	23.13 ± .233	20.77 ± .175	18.12 ± .171	16.55 ± .122	17.10 ± .102	16.00 ± .129	90.62	62.50	9.38	17.71
" "	3	22.98 ± .173	20.27 ± .244	18.92 ± .242	16.81 ± .160	17.64 ± .174	16.18 ± .126	88.11	59.40	11.89	25.75
7. $NaNo_3$ 15#	1	22.27 ± .178	20.75 ± .175	17.54 ± .199	16.87 ± .115	16.11 ± .109	16.52 ± .155	83.51	29.67	16.49	53.85
" "	2	22.97 ± .142	20.03 ± .145	19.21 ± .112	17.74 ± .148	16.06 ± .132	16.18 ± .167	85.71	37.36	12.08	42.84
" "	3	22.56 ± .158	20.30 ± .220	19.07 ± .136	16.53 ± .114	16.04 ± .096	16.41 ± .106	81.60	37.93	16.09	41.37
8. Check	1	23.72 ± .144	21.82 ± .188	17.82 ± .118	17.38 ± .117	18.00 ± .168	17.22 ± .105	97.67	59.30	2.33	23.26
"	2	22.93 ± .210	21.54 ± .174	18.54 ± .129	16.80 ± .137	17.12 ± .133	16.13 ± .108	93.47	43.47	6.53	39.13
"	3	22.64 ± .179	20.17 ± .166	17.60 ± .184	17.03 ± .173	16.80 ± .106	16.42 ± .104	81.18	53.46	18.82	30.70

The check fruit was a trifle over a pound firmer at the beginning of the storage period than the fruit from the nitrate of soda plots. Samples from the nitrated plots were secured from three plots which had received eight, fifteen, and twenty pounds of nitrate of soda per tree respectively. The firmness of these fruits at picking time was inversely correlated with the amount of nitrogen which had been applied. By February 22 the check fruit was still a little more than a pound firmer, as indicated by the Magness and Taylor (24) pressure tester, than the fruit from the nitrogen plots. At this time, February 22, there was still a tendency for the fruits from the nitrated plots to be less firm as the amount of nitrogen applied was increased. These differences were small, however, amounting to only a few tenths of a pound. The differences in the firmness of these fruits at picking time were the same as at the end of the season. For this reason the actual amount of softening in storage was little influenced by the application of eight, fifteen, or twenty pounds of nitrogen.

The storage counts showed no differences in the percentage of sound and unsound fruits between fruits from the check and nitrated plots until after February 22. Unfortunately the records for the check fruit obtained on March 29 were lost, but there seemed to be a tendency for the application of greater amounts of nitrogen to result in a

smaller percentage of sound fruit late in the season. However, the percentage of scalded fruits was greater with the increased amounts of nitrogen applied. It seems probable that the differences in the amount of sound fruit in this sample were correlated with the factors responsible for the decreased color of the fruit from the fertilized plots, which resulted in more scald.

Summary. There was a tendency for the fruit from the fertilized plots to be softer, both at picking time and in storage, than the fruit from the check plots. The difference (a little over a pound) is of doubtful significance. The amount or the rate of softening was equal when fruit from checkplots or fruit from trees receiving applications of eight, fifteen and twenty pounds of sodium nitrate were used. Nitrogen applications have caused an increase in the amount of scald probably associated with the decreased color on this fruit.

Investigations Conducted in 1930.

Because of the exceedingly dry growing season of 1930, water was applied to these plots during the months of August and September. This enabled the fruit to size up well in spite of a heavy crop, and some trees had more than thirty bushels of fruit.

Pressure Tests and Storage Studies

Triplicate samples of one bushel each were taken on October 16, 1930. All three bushels were used for

pressure testing and also for storage counts. Firmness of fruit from plots which received fifteen and twenty pounds of nitrate per tree was compared with fruit from the check plot.

Results. Pressure test results (table 16) show that at picking time, October 16, there was some variation in the firmness of the fruits from the different fertilizer plots, but these are small (a little over a pound) and when the three bushels for each treatment are considered the differences are seen to be insignificant. As the season advanced the firmness of all the fruits decreased, but the decrease was fairly uniform for fruits from all the treatments. By the end of the storage season, (April 20) the fruit was still firm (testing about sixteen pounds with the Magness and Taylor (24) tester). At this time there is no difference in the firmness of fruits from the check plots as compared to nitrated plots.

No scalded or decayed fruits appeared in the samples from any of the plots until March 6. The counts made on this date revealed no significant differences in the percentage of sound or scalded fruits from the different treatments (table 16). There was a tendency, however, for the fruit from the plot receiving fifteen pounds of nitrogen to have more scald and less sound fruits than either the fruits from the plot which received twenty pounds of sodium nitrate per plot or the fruit from the check plot of the other two plots. The variability existing among the

TABLE 17

Firmness of Yorks, Greenlane, Hancock, Maryland, 1928.
(Pressure tested with Magness and Taylor tester using 7/16 inch plunger)

Fall Application	Spring Application	Picked and tested Oct. 11, 1928:	Picked Oct. 10, 1928: Tested Dec. 14, 1928:	Picked Oct. 10, 1928: Tested Jan. 19, 1929:	Picked Oct. 10, 1928 Tested Mar. 1, 1929.
	NH 7.5#	19.1 ± .20	18.0 ± .10	15.82 ± .155	15.74 ± .148
NH 7.5 #		19.7 ± .19	18.5 ± .23	16.73 ± .010	16.74 ± .134
	NO 10#	19.5 ± .17	18.9 ± .10	19.10 ± .192	17.30 ± .161
NO 5#	NO 5#	20.1 ± .19	20.7 ± .11	18.62 ± .182	17.22 ± .207
NO 10#		18.6 ± .14	20.0 ± .10	18.90 ± .176	16.85 ± .182
	NO 10#	21.8 ± .15	18.6 ± .14	17.42 ± .187	16.80 ± .167
NO 10#		20.8 ± .31	19.3 ± .12	17.70 ± .100	17.00 ± .071
	NO 10#	21.4 ± .25	19.2 ± .10	17.34 ± .161	17.20 ± .148
	NH 7.5	21.7 ± .20	17.9 ± .12	17.40 ± .063	16.19 ± .190
NH 7.5#		21.7 ± .12	20.0 ± .14	18.18 ± .070	16.59 ± .077
NH 3.75#	NH 3.75	19.9 ± .22	18.8 ± .19	17.40 ± .228	15.20 ± .122
Check	Check	20.7 ± .27	17.9 ± .10	16.93 ± .184	16.54 ± .179
NO 5#	NO 5#	20.6 ± .28	19.7 ± .13	17.62 ± .141	17.45 ± .237
NO 10#	NO 10#	19.1 ± .22	17.9 ± .12	16.52 ± .105	16.88 ± .253
	NO 20#	18.8 ± .14	19.2 ± .11	15.63 ± .127	16.70 ± .063
	NO 15#	19.0 ± .22	19.0 ± .17	18.39 ± .117	18.80 ± .253
NO 5#	NO 5#	19.2 ± .25	18.0 ± .14	17.10 ± .130	16.87 ± .152
	NH 11.25#	21.1 ± .26	20.0 ± .10	18.48 ± .090	17.79 ± .095
NH 15#		19.2 ± .27	18.6 ± .14	15.01 ± .134	14.73 ± .055
	NH 15#	19.4 ± .26	19.4 ± .10	17.02 ± .155	17.14 ± .095
	NO 20#	21.3 ± .24	21.2 ± .16	18.68 ± .161	18.62 ± .173
NO 20#		20.6 ± .26	18.9 ± .16	18.22 ± .167	17.14 ± .095

Percentage of Sound Fruit.

	Jan. 19	Mar. 1
20 # NaNo3	80.18	32.43
10 # NaNo3	79.62	28.70
Check	80.00	20.83

triplicate samples of each plot was rather high. By April 20, there was a considerable difference in the amount of scalded and sound fruit. The fruit from the check plot and the plot receiving twenty pounds of nitrate showed about the same percentage of sound and decayed fruits, while the fruit from the plot receiving fifteen pounds of nitrate had a larger amount of scald and a smaller percentage of sound fruits.

It is difficult to attribute this difference directly to the use of the nitrogen fertilizer, since the fruit from the plot which received the most nitrogen showed less scald than the fruit from the plot which was fertilized less heavily.

Summary. The pressure test studies of 1930 (table 16) indicate that applications of fifteen or twenty pounds of sodium nitrate have had no significant effect on the firmness of the flesh of the fruits as compared with check fruits, either at the time of picking or during the storage period. The variations among the individual baskets of each sample are as great as the variations among the samples.

The results of the storage investigations relative to scald and decay were so variable as to warrant no conclusions.

Summary of York Apples at Tonoloway

Climatic conditions during the growing season seem to have affected the keeping quality of the fruit in different years.

Following the wet growing season of 1928 the fruit from the fertilized plots showed a greater rate of softening than the check fruit. No differences in the rate of softening were evident during the dryer seasons of 1929 and 1930. During the exceptionally dry season of 1930 fruit from the plot receiving fifteen pounds of sodium nitrate per tree showed greater susceptibility to scald than the check fruit while fruit from the plot which received twenty pounds of sodium nitrate per tree showed about the same amount of scald as the check fruit. A dry season cannot have been the cause of this, however, since these trees were irrigated during the summer months.

YORK IMPERIAL APPLES, GREEN LANE, HANCOCK, MARYLAND

Description of Orchard and Plots. The Green Lane orchard also is located on the eastern slope of a steep ridge in Western Maryland, about three miles north of Tonoloway orchard. Fertilizer treatments began in 1924 in this orchard, when the trees were about twenty years old.

The experiment was planned so that the plots would run from the base to the top of the slope. This eliminated, to a large extent, any crossfeeding between plots. Each plot contained eighteen trees planted 33 x 33 feet.

The soil was a Berks shale* and a system of sod mulch had been employed.

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* Soil Survey of Washington County, Maryland by Bureau of Soils, U.S.D.A. in cooperation with Maryland Geological Survey and Maryland Agricultural Experiment Station.

At the beginning of this investigation the check trees were smaller and making about two to three inches of terminal growth, while the nitrogen trees were making from ten to fifteen inches terminal growth. Increase in trunk circumference is shown in table 1. Nitrogen was applied at the rate of ten, fifteen, and twenty pounds of sodium nitrate per tree.

Some trees received the fertilizer in the spring, about three weeks before blossoming, others received it in the fall, while some trees received half of the fertilizer in the spring and half in the fall.

Investigations Conducted in 1928

In 1928 the check trees were in a poor state of vigor and fruitfulness while the fertilized trees were making good annual growth and bearing good crops as is indicated in table 1.

Pressure Tests and Storage Studies

In 1928, a one bushel sample of fruit was taken from each of the plots studied and held at 32°F. from October 10 to March 1.

Results. At time of picking, fruit from the check plot tested slightly higher than the average test of the fruit from the nitrated plots. Although the fruits from some of the nitrate plots were firmer, the differences at picking time, however, were not significant. At the end of the storage season, fruit from the nitrated plots

averaged firmer than fruit from the check plot, but the differences were significant only for fruit from two plots receiving fifteen and twenty pounds of sodium nitrate per tree respectively (table 17). The pressure tests indicate that the rate of softening was greater for the fruits from the check plots than for those from the fertilized plots, but this difference is very slight and not significant. There were no differences in the percentage of sound fruits from these plots on January 19, but by March 1 there was a slightly greater amount of sound fruit in the fertilized samples. The differences were not great (table 17)

Summary. Nitrogen applications on York apple trees resulted in a slight, though not significant, decreased rate of softening of the fruits compared to fruit from the check plot. Likewise nitrogen fertilizers have had practically no influence on the percentage of fruits breaking down in storage.

Investigations Conducted in 1929

In 1929 the check trees were making less growth (table 1) and had lighter green foliage than the fertilized trees. The fruit was a little more highly colored.

Pressure Tests and Storage Studies.

Duplicate samples of one bushel each were obtained in 1929 from some of these same plots. No samples were obtained from the plot receiving twenty pounds of sodium nitrate. The fruit from the check plot and fruit

TABLE 18.

Firmness of Greenlane Yorks 1929. Hancock, Maryland.

(Firmness of Flesh as Tested by Magness and Taylor Tester using 7/16 inch plunger.)

Plot	Treatment: Fall	Treatment: Spring	Oct. 6	Nov. 8	Dec. 6	Jan. 10	Feb. 22	March 29
9#1	NO_3	10#	22.20 ± .119	19.88 ± .127	19.82 ± .055	18.32 ± .211	15.21 ± .146	15.58 ± .130
9#2	NO_3	10#	21.50 ± .155	21.38 ± .152	20.08 ± .089	18.47 ± .119	17.18 ± .216	16.18 ± .185
13#1	Check		22.58 ± .063	19.72 ± .165	18.78 ± .084	18.14 ± .159	15.13 ± .115	15.71 ± .124
13#2	Check		21.92 ± .161	19.42 ± .207	20.08 ± .145	17.61 ± .177	15.31 ± .131	15.28 ± .104

TABLE 19.

Firmness of York Apples at Greenlane 1930 at Picking Time and During Storage.

(Pressure Test in Pounds Using Magness and Taylor Tester with 7/16 inch plunger.)

Treatment	Oct. 16	Nov. 29	Jan. 8	Feb. 9	March 7	April 20	Percent Sound Fruit April 20
$NaNO_3$ 20# 1	22.75 ± .134	20.76 ± .164	18.42 ± .118	19.05 ± .169	17.18 ± .178	15.98 ± .071	
$NaNO_3$ 20# 2	22.76 ± .198	21.92 ± .210	18.05 ± .101	18.90 ± .089	18.07 ± .167	16.91 ± .135	
$NaNO_3$ 20# 3	22.33 ± .215	20.57 ± .191	17.31 ± .100	18.81 ± .156	17.32 ± .128	16.85 ± .170	54.53
$NaNO_3$ 10# 1	23.65 ± .245	22.07 ± .148	18.71 ± .113	19.64 ± .182	18.51 ± .167	17.57 ± .200	
$NaNO_3$ 10# 2	23.02 ± .220	22.12 ± .121	19.78 ± .152	18.97 ± .145	18.38 ± .124	18.54 ± .162	
$NaNO_3$ 10# 3	22.57 ± .131	21.54 ± .070	18.05 ± .133	18.86 ± .158	18.05 ± .198	18.25 ± .227	56.23
Check 1	21.35 ± .178	20.95 ± .140	17.71 ± .161	17.74 ± .151	17.03 ± .142	17.85 ± .152	
Check 2	22.31 ± .209	21.83 ± .142	18.60 ± .130	19.12 ± .161	19.00 ± .242	17.41 ± .177	
Check 3	21.95 ± .205	20.88 ± .150	17.58 ± .138	18.30 ± .118	16.86 ± .275	16.52 ± .158	60.67

from the plot receiving ten pounds of sodium nitrate show little difference in pressure test during the storage season (table 18). While the check fruit is about 0.3 of a pound firmer at picking time and about 0.3 of a pound softer at the end of the storage than fruit from the nitrate plot, variation in the test of the fruit from the two samples from each treatment renders the slight difference insignificant.

No differences appeared in the percentage of sound fruits from the different fertilizer plots in this orchard (table 18). No scald or breakdown appeared on the fruit from any of the plots regardless of the fertilizer treatment.

Summary. Practically no differences appeared in the firmness of flesh or rate of softening of this fruit in storage. Furthermore, there were no differences in the amount of scald or breakdown in storage as a result of nitrogen fertilization.

Investigations Conducted in 1930

The fruit in the Green Lane orchard in 1930 was medium sized (2-3/4 inches) fairly well colored, and exceptionally free from blemishes such as sooty blotch.

Pressure Tests and Storage Studies.

On October 16, 1930, a four-bushel sample of fruit was obtained from each of three plots, plot 18 (sodium nitrate -- twenty pounds per tree), plot 4 (sodium nitrate -- ten pounds per tree), and plot 13 (check). One bushel

TABLE 20.

Chemical Composition of York Apples from Green Lane Orchard, 1930, as Affected by Nitrogen Fertilizers.

Treatment	Date	Reducing Sugars	Total Sugars	Sucrose	Starch	Acid Hydrolyzable Substances	Total Carbohydrates	Dry* Weight	Pectin as Calcium Pectate: Total*	Soluble*	Proto.*	Total N.	Ph. of Juice	cc Alkali to neutralize 10 cc juice
$NaNO_3$ 20#	Oct.16	41.42	56.10	14.68	10.39	18.93	75.03	18.04	.827	.071	.756		3.23	9.27
"	Nov.29	45.98	67.45	21.47	2.46	9.34	76.79	18.00	.820	.064	.756	.310	3.33	9.12
"	Jan.8	51.19	69.33	18.14	Trace	7.20	76.53	18.01	.784	.120	.664		3.27	8.15
"	Feb.10	50.58	69.66	19.08	Trace	5.96	75.62	17.62	.800	.141	.659		3.61	7.95
"	Mar.7	52.94	69.88	16.94	------	6.26	76.14	18.05	.762	.157	.605		3.50	7.87
$NaNO_3$ 10#	Oct.16	39.52	59.34	19.82	8.74	16.58	75.92	17.42	.859	.062	.797		3.36	9.60
"	Nov.29	44.00	67.03	23.03	2.58	9.03	76.06	17.97	.856	.060	.796	.275	3.38	9.16
"	Jan. 8	46.80	66.78	19.98	Trace	8.07	74.85	18.04	.815	.115	.700		3.40	8.65
"	Feb.10	47.34	66.08	18.74	Trace	6.14	72.22	17.92	.830	.147	.683		3.52	8.41
"	Mar.7	49.23	65.56	16.33	------	6.88	72.44	18.43	.788	.149	.639		3.59	8.28
Check	Oct.16	38.88	59.63	20.75	8.29	11.71	76.34	16.92	.811	.065	.746		3.37	9.61
"	Nov.29	44.04	68.78	24.74	2.51	10.47	79.25	17.32	.852	.052	.800	.225	3.45	9.25
"	Jan.8	45.23	69.88	24.65	Trace	7.01	76.89	17.34	.757	.116	.641		3.30	8.45
"	Feb.10	47.40	68.11	20.71	Trace	6.41	74.52	17.05	.834	.141	.693		3.54	8.20
"	Mar.7	44.29	69.22	24.93	------	6.55	75.77	17.00	.776	.156	.620		3.59	8.12

*Expressed on Fresh Weight Basis. Rest of Table on Dry Weight Basis.

from each plot was kept for respiration studies, while the other three were sampled at intervals for pressure testing, storage counts and chemical analyses.

Results. The pressure test results, table 19, indicate that there were no significant differences in the firmness of the fruit at picking time. On April 20 when the last test was made, one basket of fruit from the plot receiving twenty pounds of nitrate per tree was softer by nearly two pounds than the fruit from the check plot, the difference being barely significant. The difference was not significant for fruit in the other two baskets.

No scald developed on this fruit until after March 7. On April 20 a considerable portion of the fruit had scalded as indicated in table 19. (Scalded fruits are included under unsound fruit). While the table shows an increase of scald with the larger applications of nitrogen, the fruit was of somewhat poorer color and the differences were small.

Summary. This year's study on York Imperial apples has revealed no differences in the amount of breakdown in storage between fruit from plots which received fifteen or twenty pounds of sodium nitrate and check. There was a tendency for the fruit from the plot which received twenty pounds of sodium nitrate to be softer at the end of storage than fruits from plots which received ten pounds of nitrate or which received no fertilizer. The tendency is not consistent enough to be considered significant.

Chemical Studies.

At intervals during storage, samples were taken for chemical analyses. These samples were obtained from the fruits which had been pressure tested. Four samples were taken each time for a given lot of fruit. Two were used for determining the pectic substances, and two for carbohydrate analysis, including total sugars, reducing sugars, sucrose (by difference), starch and alcohol-insoluble-acid hydrolizable materials.

Samples of the juice were obtained also for the determination of the hydrogen-ion concentration and the total acidity.

Results. The results of the chemical studies are given in table 20. As with the Stayman apples from Olney, Maryland, previously discussed, the percantage of reducing sugars increased with increased in the quantity of nitrogen applied. However the total sugars did not show this difference and when the starch and acid hydrolizable materials are taken into consideration, the total carbohydrates show no very great differences. Wallace (37) shows an increase in total sugars and sucrose when fruit from nitrated trees in sod was compared with fruit from trees in sod which were not nitrated.

There was an increase in both total and reducing sugars in fruits from all plots during storage until the first of January. Although there was a trace of starch left at this time, the fruit apparently was using

TABLE 23.

Gandy Strawberries, 1928

Picked June 5, 1928.

Treatment	Per cent Soft					Per cent Decayed				
	Test 1	Test 2	Test 3	Test 4	Ave.	Test 1	Test 2	Test 3	Test 4	Ave.
Check	6.1	23.5	34.9	33.4	35.3	15.5	16.9	3.9	18.6	13.7
$NaNO_3$	2.9	23.0	36.5	18.7	20.3	14.2	16.9	8.5	46.2	21.4
$(NH_4)_2SO_4$	9.2	31.7	53.0	22.1	29.0	13.3	13.4	8.1	57.8	23.1

TABLE 24.

Gandy Strawberries, 1928

Picked June 8, 1928.

Treatment	Per cent Soft				Per cent Decayed				
	Test 1	Test 2	Test 3	Ave.	Test 1	Test 2	Test 3	Ave.
Check	1.7	16.4	19.7	12.6	15.5	22.7	17.7	18.6
$NaNO_3$	6.1	9.8	20.7	12.2	27.0	40.9	19.1	29.0
$(NH_4)_2SO_4$	8.5	17.75	34.3	20.1	26.4	27.6	18.1	24.0

Test 1 — Stored at 35° F (15 hrs.—— 24 hrs. total)
Test 2 — Stored at 70°-80° F. (24 hours).
Test 3 — Pony refrigerator to College (48 hours).
Test 4 — Seventy miles by truck (24 hours).

sugar for respiration faster than it was being formed. As a result both the total and reducing sugar content decreased after January 1.

The figures for total pectin content during storage indicate that this substance is also being used for the formation of sugars and for respiratory purposes. Appleman and Conrad (3) have shown that the total pectin content of peaches changes but little during the ripening process. Haller (13-a) reports that the total pectic material in apples may increase in storage. This loss of total pectin is less noticeable with the York variety than with the Stayman variety previously discussed.

The increase in the soluble pectin content was very similar for the fruits from all plots. This was to be expected in view of the pressure test results, since the pectic changes are considered to be closely associated with softening of the flesh. The decrease in total pectin tends to mask the increase in soluble pectin, since it is the soluble pectin which is broken down and used in the respiratory activity of the fruit. The decrease in protopectin is not affected by the loss of total pectin, and for this reason it is a more pertinent index of the ripening process than is the increase in soluble pectin. No differences were apparent in the total pectin content as a result of the fertilizer treatment.

The greater sugar content in fruit from the nitrogen plot is very closely associated with an increase

in the actual nitrogen content of the fruit. The fruit from the plot receiving twenty pounds of sodium nitrate per tree showed an increase of 37.7 per cent total nitrogen over the check. Gourley and Hopkins (13) report an increase of better than one-hundred per cent in some cases, while Lagasse (22) reports only 18.7 per cent increase in Delaware. It seems that the percentage increase varies greatly with the variety and general vigor of the tree, as well as with the crop the tree is bearing.

There is a slight increase in dry weight of the fruit from the fertilized plots compared with the check fruit. Gourley and Hopkins (13) show a decrease in per cent dry weight with increased nitrogen content while Wallace (37) shows an increase. In spite of this increase in percentage dry weight there is evidence of an increase in reducing sugars on a dry weight basis. It is obvious that the differences in the reducing sugar content would be greater than are indicated by the figures in table 20, if they had been based on the fresh weight of the fruit.

The total titratable acidity decreased steadily throughout the storage period.

The Ph on the other hand did not change much, although there was a slight increase. No very large differences in Ph or total acidity were apparent between the fruit from the different plots, although there was a tendency for the fruit from the double nitrated plot to have

a lower Ph but also a slightly lower acidity. Gourley and Hopkins (13) also show no significant differences in the Ph of fruit from different fertilizer plots. Wallace (37) shows no consistent differences in acidity which can be attributed to nitrogen fertilization.

Summary. The application of nitrogen to the soil has resulted in an increase in the total nitrogen content of the fruit of 37.7 per cent over check fruit. Associated with the increased nitrogen content has been an increase in the sugar content. Pectin and acidity changes were not affected by the fertilizer treatment.

Respiration Studies

Seven to eight kilograms of fruit were placed in the respiration chambers, duplicate samples being taken from each of the storage samples. Detailed description of the methods and apparatus are given in the appendix. A diagram of the apparatus used for respiration studies is shown in figure 10.

Results. The respiration results, figure 9, are expressed on a percentage basis, the check equalling one-hundred per cent. There was very little difference in the respiration rates of the fruit from the two fertilized plots. The fruits from these two plots respired about eight per cent faster than the check fruit. In order to remove the fluctuations caused by variations in the water pressure, (see appendix), a straight line of closest fit

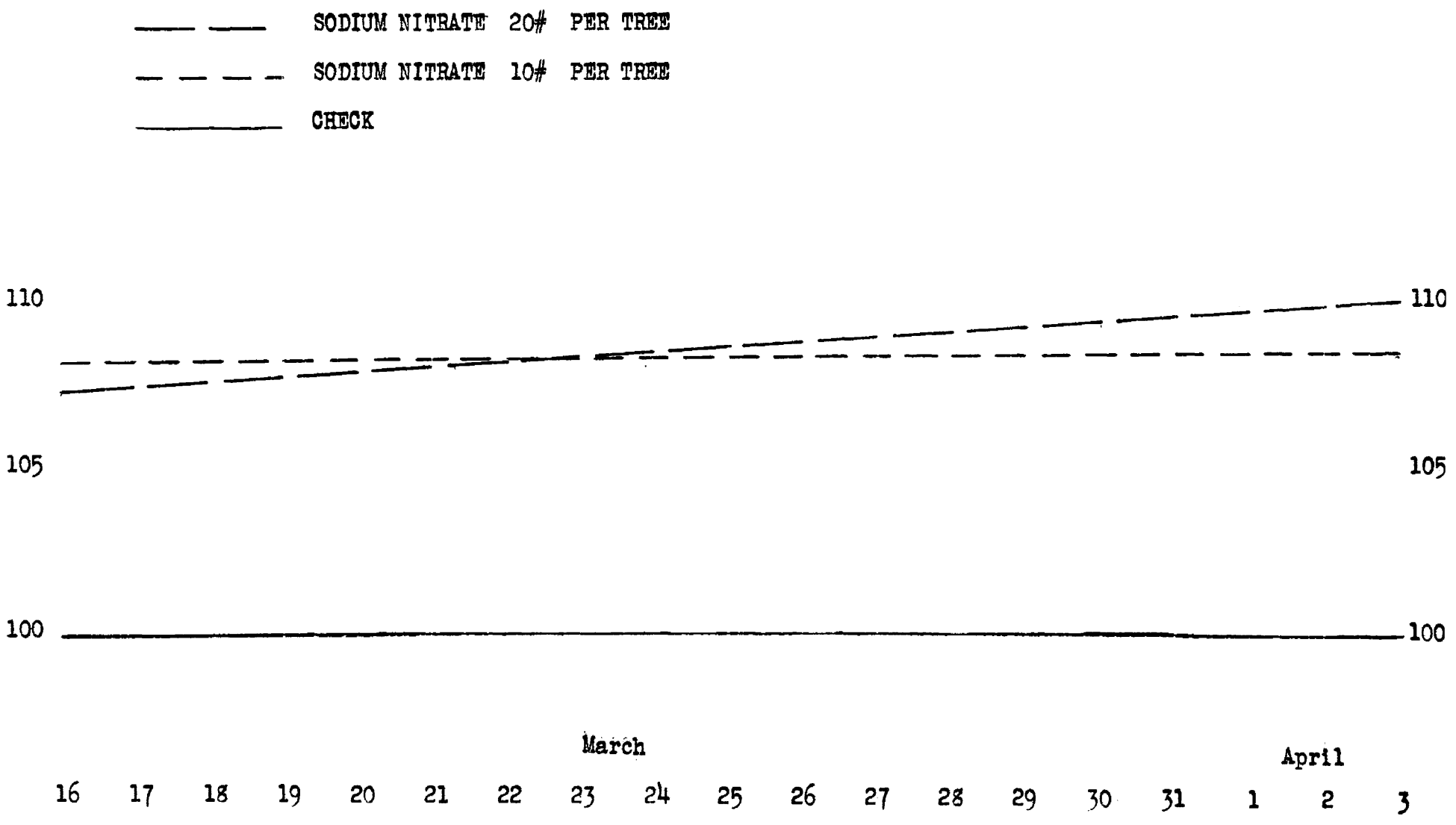

Figure 9.

Respiration rate of fruit from the nitrated plots of York apples from March 16 to April 3, as compared with the respiration rate of the check as 100.

has been constructed for the data from each of the fertilizer plots. The difference in the respiration rate is correlated with the nitrogen content of the flesh, with the York, in the same manner as with the Stayman. Plagge (33) cites Harding as finding that Grimes apples, which had been fertilized with nitrogen, showed a greater respiratory activity than fruits from unfertilized trees.

Summary of York Apples at Green Lane

Over a period of three years, nitrogen fertilizers have resulted in no change of commercial importance in firmness or in the rate of softening of the fruit in storage. The fertilizer has caused no change in the amount of decayed fruits in storage and except where there was a reduction in color has had no effect on scald.

Increased nitrogen applications to the soil have resulted in increases in the nitrogen content of the flesh of the fruits. Total sugars, reducing sugars and starch were increased with nitrogen applications while sucrose and acid hydrolyzable material were decreased. On a dry weight basis the total acid hydrolyzable carbohydrate content was little changed by the fertilizer treatment, but on a fresh weight basis the carbohydrate material was increased with applications of nitrogen fertilizers. There was no influence of fertilizer treatment on the changes in the pectic materials. Nitrogenous fertilizers applied to the soil under the spread of the limbs has resulted in a slightly

increased rate of respiration of the fruits from these respective trees. Although these chemical changes were consistent, there were no corresponding changes in the keeping quality of the fruit as measured by the mechanical means.

General Discussion of Apple Results

The results obtained in this investigation, covering a period of four years, agree in most respects with work of other investigators studying the effects of fertilizers on the keeping and storage quality of fruits. In most cases nitrogen fertilizers have had no significant effect on the firmness of the flesh of apples either at picking time or during storage. In cases where the differences were statistically significant, the differences were not of commercial importance.

The increase in the sugar content with increased nitrogen applications is in accord with the results obtained by Gourley and Hopkins (13) and by Wallace (37).

Decreases in the quantity of protopectin during the ripening of apples in storage may be used as a measure of softening but the results indicate that the pressure tester may be more sensitive.

Gourley and Hopkins (13) and Lagasse (22) have shown that increasing the nitrogen content of the fruit did not injure the keeping quality. This conclusion has been reached in this study within limits. If we assume that

increased respiration is an indication of poor keeping quality, then the nitrogen applications have had a slightly injurious effect on keeping quality. If, on the other hand, we assume that the increased respiration rate accompanying increased nitrogen applications is merely a reflection of the increased sugar content, then nitrogen fertilizers have not been injurious to the keeping quality. This latter assumption appears to the author to be more probable than the first. If the first assumption were correct, one would expect to find indications of the injury, such as more rapid rate of softening, more breakdown in the storage, etc. Since these differences have not shown up it seems that the increased rate of respiration is a secondary factor and is not an indication that the fruit from the fertilized plots has poorer keeping quality.

Plagge (33) has reported that applications of nitrogen to the soil have resulted in an increased susceptibility to soggy breakdown with Grimes apples. No soggy breakdown or low temperature injury was encountered in this work.

Though shipping tests have been limited in this study, no effect of nitrogen on the shipping quality of apples as measured by pressure tests, has been found. In some cases scald has been a little more prevalent on the nitrated fruit, but where no differences in color were evident, scald was not associated with nitrogen applications.

General Summary of Apple Results

In most instances, nitrogen applications have been associated with a decrease in the rate of softening of the fruit in storage. Correlated with softening has been a decrease in the protopectin content.

Fertilizing with nitrogen has resulted in an increased nitrogen content of the fruit.

Accompanying nitrogen fertilization has been an increase in the respiration rate of the fruit. There was also an increase in the sugar content of the fruit from the fertilized trees as compared with fruit from the check trees. This increased sugar content may have been responsible for the increased rate of respiration with the fertilized fruit. There has been a little more scald on the nitrated trees, however, scald has not been a serious problem with apples in this study.

No correlation was found between the chemical changes which occurred and the keeping quality of the fruit.

II. STRAWBERRY INVESTIGATIONS

The strawberry investigations were begun in the spring of 1928,* using plots in the Marion section of Somerset County on the southern end of the Eastern Shore. Because of the custom in Maryland of removing beds after one or two years, it was necessary to start new plots in 1929. These plots and also plots started in 1930 were located in the Pittsville section of Wicomico County. The Missionary, Gandy, Premier and Chesapeake varieties were used for study in this investigation. The work was carried on in cooperation with commercial growers of strawberries. An attempt was made to use fruit which had been picked by the regular pickers, but the fruit thus selected varied so much in the amount of bruising that it could not be used. As a consequence all the samples were picked by the Experiment Station employees and consisted of fruit as nearly as possible of the same size and degree of maturity.

Several methods of pressure testing were tried but none proved to be adequate as a measure of shipping quality, since no correlation was found between such measurements and shipping tests. This is in agreement with the results obtained by Shoemaker and Greve (35).

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*The investigations were carried on in 1928 by A. Lee Schrader and W. E. Whitehouse.

The types of storage and shipping tests are given in connection with the discussion of the individual varieties. Detailed chemical procedure is given in the appendix.

MISSIONARY

The plots in this patch, located at Marion in Somerset County, consisted of one-thirtieth of an acre and were located on an Elkton loam soil of good fertility. Sodium nitrate at the rate of 150 pounds per acre was applied to some plots in the first year of bearing, while other plots received the equivalent of this quantity of nitrogen in the form of ammonium sulphate. Fruits from these plots were compared with fruits from plots which received no fertilizer.

Investigations Conducted in 1928

Two pickings were made of this variety in 1928, the fruit being subjected to several types of holding tests, following picking. The tests are as follows:

Test 1 Stored 20 hours at 35°F. Twelve mile haul, total time 30 hours.

Test 2 Holding test at 60 - 70°F. for 24 hours.

Test 3 Pony refrigerator to College. Forty-eight hours.

Test 4 Seventy miles by truck. Twenty four hours.

No differences were evident between the fruits from the nitrogen fertilized plots and the fruits from the check plots in the percentage of soft or of decayed fruits with either the first or second picking. In the second pick-

TABLE 21.

Missionary Strawberries, 1928.

Picked May 26, 1928

Treatment	Per cent Soft.					Per cent Decayed.				
	Test 1	Test 2	Test 3	Test 4	Ave.	Test 1	Test 2	Test 3	Test 4	Ave.
Check	53.1	35.8	8.6	57.1	38.6	9.2	28.9	6.1	12.5	14.2
$NaNO_3$	60.2	44.6	8.3	40.4	38.4	15.6	23.4	8.3	12.2	14.9
$(NH_4)_2SO_4$	49.6	44.2	7.6	39.7	35.3	24.5	18.1	7.6	15.6	16.4

TABLE 22.

Missionary Strawberries, 1928.

Picked May 29, 1928.

Treatment	Per cent Soft.					Per cent Decayed.				
	Test 1	Test 2	Test 3	Test 4	Ave.	Test 1	Test 2	Test 3	Test 4	Ave.
Check	5.8	10.1	9.2	7.9	8.2	1.9	6.8	4.2	6.3	4.8
$NaNO_3$	12.1	5.6	5.4	12.4	8.9	6.4	2.8	2.9	8.4	5.1
$(NH_4)_2SO_4$	14.2	6.0	7.3	6.1	8.4	4.7	5.3	4.2	5.4	4.9

Test 1 — Stored 20 hours at 35° F., Twelve mile haul, Total time 30 hours.
Test 2 — Holding test at 60-70° F. for 24 hours.
Test 3 — Pony refrigerator to College, 48 hours.
Test 4 — Seventy miles by truck, 24 hours.

ing, however, where the fruits were subjected to a seventy mile haul by truck, there was a greater amount of soft and of decayed fruits in the sample from the sodium nitrate plot as compared to the fruit from thecheck plot and the ammonium sulphate plot. However this same fruit from the nitrogen plots in the other tests showsless soft and decayed berries than fruit from the check plot or the ammonium sulphate plot, so that the average of the four tests shows no difference.

Summary of Missionary. The average results obtained with four types of holding tests, indicate that fertilizers have not influenced the softening or the amount of decay of the fruits. When the individual tests are considered, however, there is an indication that the fruits from the sodium nitrate plot held up somewhat better than the check in the holding test and refrigerated haul, but did not hold up as well in the hauling tests at ordinary temperatures.

GANDY

These plots consisting of one-thirtieth of an acre were located in the Marion district in Somerset County at the southern end of the Shore. The soil is classified as an Elkton loam, and was in a good state of fertility. The plants were making a uniform growth. The nitrogen plots received either sodium nitrate at the rate of 150 pounds per acre or the equivalent of this quantity of nitrogen in the form of ammonium sulphate.

Investigations Conducted in 1928

Two pickings were made in 1928 -- sixteen quarts beingpicked from each plot at each picking. The fruit of each picking received the following treatments:

Test 1 Stored at 35°F. (15 hours -- 24 hours total).

Test 2 Stored at 70 - 80°F. (24 hours).

Test 3 Pony refrigerator to College (48 hours).

Test 4 Seventy miles by truck (24 hours).

The keeping quality of the fruit from fertilized plots was compared with the keeping quality of fruit from plots which received no fertilizer. The percentages of soft and of decayed berries at the end of the storage period were used as the criteria of keeping quality. Tables 23 and 24 show no consistent differences between fertilizer treatments for the two pickings, in the percentage of soft fruit. The check plot, however, had a smaller percentage of decayed berries in both pickings at the end of the storage than the fertilized plots. The increased amount of decay for the fertilized fruit in the first picking as indicated by the average of the four tests was caused almost entirely by the fourth test, i. e. the seventy mile haul by truck. With the holding tests and the refrigerated shipment there were no differences.

In the second picking, however, the difference appeared to be cumulative, some increase in percentage decay being evident for all three tests.

TABLE 9

Firmness of Stayman Apples, Salisbury, 1928, at Picking Time and During Storage.

(Picked Oct. 2, Held in Cold Storage 32°)

(Pressure Tested in Pounds with Magness and Taylor Tester Using 7/16" Plunger)

	Plot Treatment	Oct. 3, 1928	Dec. 8, 1928	Feb. 1, 1929	Mar. 15, 1929	Total Decrease in Firmness
1	$(NH_4)_2SO_4$ double	17.17 ± .173	13.59 ± .105	12.11 ± .084	11.52 ± .078	5.65
2	$(NH_4)_2SO_4$ single	17.95 ± .109	14.47 ± .100	12.64 ± .089	12.24 ± .135	5.71
3	$(NH_4)_2SO_4$ Lime	18.42 ± .197	14.70 ± .134	12.37 ± .114	11.86 ± .100	6.56
4	Check	17.32 ± .127	14.00 ± .071	12.01 ± .071	10.40 ± .095	6.92
5	Nitrate Lime	18.66 ± .187	13.14 ± .114	12.40 ± .119	11.11 ± .145	7.55
6	$NaNO_3$ single	18.17 ± .187	13.94 ± .063	12.83 ± .107	11.67 ± .119	7.05
7	$NaNO_3$ double	17.62 ± .181	13.50 ± .078	12.12 ± .064	11.33 ± .089	6.29
12	$NaNO_3$ Aug. 1	17.80 ± .181	13.59 ± .130	12.71 ± .110	11.98 ± .145	5.82
13	Check	17.66 ± .130	14.42 ± .109	12.23 ± .105	11.81 ± .089	5.85
14	N-P-K	17.02 ± .161	12.42 ± .105	10.86 ± .089	10.70 ± .105	6.32
17	$NaNO_3$ Sept. 1	17.11 ± .109	13.25 ± .063	11.76 ± .084	10.58 ± .089	6.53
18	Acid Phosphate	17.06 ± .200	12.48 ± .055	11.42 ± .100	10.67 ± .078	6.39
19	Muriate of Potash	17.02 ± .158	12.40 ± .071	11.13 ± .175	10.34 ± .078	6.68
20	Acid Phosphate KCl	16.60 ± .114	13.98 ± .044	11.35 ± .084	10.46 ± .044	6.14
21	$NaNO_3$ Acid Phos.	16.09 ± .105	13.81 ± .095	11.55 ± .078	11.34 ± .084	4.79

Summary of Gandy. One year's study of the Gandy variety indicates that nitrogen fertilizers have had no effect on the softening of the fruit in storage, but has increased the susceptibility to decay, especially in warm storage.

PREMIER

In the spring of 1929, fertilizer applications were made on a field of Premier strawberries in the Pittsville section of Wicomico County. The plants had been set out in the spring of 1928. The soil was a Portsmouth fine sandy loam and the plants were in a moderate state of vigor. Each plot consisted of three rows, three feet, seven and one-half inches apart and two hundred and seventy-five feet long. The area of each plot being 1/14.5 acre. Nitrogen was applied at the rate of one hundred pounds of sodium nitrate per acre. Phosphorous was applied in addition to nitrogen to some plots at the rate of two hundred pounds of acid phosphate per acre. At the time the plots were organized, no differences in vigor of the plants were evident between the plots.

Investigations Conducted in 1929

The results obtained in 1929 are shown in table 26. No significant differences in the percentage of sound fruits appeared in either the first or second inspections of the fruit in storage. Differences were evident at the time of picking, however, in the size and

TABLE 25.

Chesapeake Strawberries, 1929.

Picked May 25 - Held at 65°F.

Treatment	Per cent Sound Average of Eight Boxes.	
	May 26	May 27
$NaNO_3$	92.1 ± .769	73.1 ± 1.93
Check	90.0 ± .667	77.2 ± .937

TABLE 26.

Premier Strawberries, 1929.

Treatment	Per cent Sound Average of Eight Boxes.	
	First Inspection	Second Inspection
$NaNO_3$	98.56 ± 3.02	69.2 ± 4.92
Check	92.15 ± 1.50	65.5 ± 5.91

appearance of the plants. The nitrated plants had larger and greener foliage than the check plants. This difference in vigor of the plants was not reflected in the keeping quality of the fruit.

In an endeavor to find some more adequate means for measuring the firmness of the berries, several types of pressure testers were tried. However none proved adequate.

Weather conditions were about normal during the spring of 1929 though the summer was dryer than normal. The dry season commenced too late to have any effect on the 1929 crop.

Investigations Conducted in 1930.

Samples were obtained from these same plots in 1930. The differences in the general appearance of the plants from the fertilized and check plots were more marked in 1930 than in 1929. This was no doubt a reflection of the dry summer of 1929. The summer of 1930 was exceptionally dry, the dry season started before the strawberry harvest was complete, though it is doubtful if the plants actually suffered much.

Weeds were prevalent in this field in 1930, as is usually the case with two year old beds. There was greater weed growth on the fertilized plots than on the check plots.

The presence of weeds is more objectionable during a dry season such as 1930, than during a season of normal

rainfall.

Pectin analyses were made on the fruit at the beginning and at the end of the storage season. The fruit from both the fertilized and check plots showed a decrease in protopectin as the fruit ripened. (See table 28) While there is less protopectin in the check fruit at the end of the storage period, than in the fertilized fruit, there is some indication that the nitrogen fertilized fruit may have softened more. There was actually a greater loss of protopectin for the nitrated fruit, but this greater decrease may be caused by differences in the rate of water loss. Shoemaker and Greve (35) report that Premier fruits from plots which received nitrogen were slightly softer than fruit from check plots. However, their differences in pressure test are very small.

General chemical analyses, (see table 28), indicate that nitrogen fertilizers have caused an increase in total sugars, reducing sugars, sucrose, acid hydrolyzable material and total nitrogen, but has resulted in a decrease in total per cent dry weight. Most of the percentage increases in carbohydrate material may be explained by the difference in dry weight of the fruit. Since the chemical samples were taken at the end of the storage season, it would appear that the fertilized fruit lost a greater percentage of water than did the check fruit. In the case of sucrose, the increase is too large to be caused by loss of moisture alone. It seems that the increase in sucrose is actually

tied up with the application of the nitrogen.

Summary for Premier. Two years results with Premier indicate that nitrogen fertilizers have had no consistent effect on the softening of the berries or on the amount of decay in storage.

Nitrogen applications have resulted in a decreased dry weight and an increased sucrose content. Other chemical differences have not been significant.

CHESAPEAKE AT PARKER'S

These plots were organized in the spring of 1929 in the Pittsville section of Wicomico County. At that time the plants had been set for one year. The soil was a Portsmouth fine sandy loam and few weeds were present. There was a good stand of strong plants in this patch. Each plot consisted of three rows, three feet six inches wide and two hundred and eighty-seven feet long, having a total area of 1/14.5 acre.

Nitrogen was applied at the rate of one-hundred pounds of sodium nitrate per acre and some plots received phosphorus in addition at the rate of two hundred pounds acid phosphate per acre.

Although the plants were very uniform when the fertilizer applications were made, by the time the berries were harvested the check plot could be detected by the lighter amount of foliage and the lighter green shade of the leaves. The differences were not great, however.

Investigations Conducted in 1929

In 1929, eight boxes of berries were picked from the check plot and eight boxes from the fertilized plots. The fruit was allowed to ripen in a well ventilated corn crib. Two examinations were made of this fruit, the soft berries being discarded each time. The results are shown in table 25. In each case, the percentages of sound berries were based on the original number of berries in each box. From table 25 it is evident that the percentage of sound fruits is not significantly different for the two treatments, (nitrate or check), either at the first or second inspection.

Investigations Conducted in 1930

By the spring of 1930 when these plants were in their second fruiting season, the difference in vigor between the check and fertilized plants was more noticeable, yet because of the richness of the soil, the check plants were more vigorous than the average non-fertilized Chesapeake plants.

A period of warm weather in May, hastened the ripening period several days with the Chesapeake variety, causing it to overlap somewhat with the Premier variety. The weather was not hot enough, however, to seriously injure the fruit.

Samples of fruit were selected from these plots in 1930 and held in the manner described for 1929. Cool

weather following the procuring of this sample prolonged its storage life. Four inspections were made during the ripening process. At each inspection the soft berries were discarded and a 100 gram sample taken from the sound berries for pectin analyses. These were preserved in alcohol as described in the appendix. At the last inspection a sample was preserved for carbohydrate and nitrogen determinations, in addition to the sample for pectin analysis.

The results of the storage counts are summarized in table 27-A. At no inspection was there a significant difference in the percentage of sound fruit, between the different fertilizer treatments. Though the fertilizer treatment had appreciably influenced the general condition of the plants, yet this difference was not reflected in the rate of softening of the fruit after picking.

The chemical studies are summarized in table 28. The check fruit showed a decrease in protopectin while the fertilized fruit showed a very slight increase. The dry weight of the fertilized fruit is about ten per cent greater than the dry weight of the check fruit. This would indicate that the fertilized fruit lost more water during storage (providing the water content was about the same at the time of picking). This greater loss of water by the fertilized fruit no doubt accounts for the increased amount of protopectin. It appears also that the differences in the total sugar, reducing sugar, and

TABLE 27.

Chesapeake Strawberries, 1930

W. Shockley's

Treatment	Per cent Sound Average of Six Boxes: First Inspection	Second Inspection	Third Inspection	Fourth Inspection
$NaNo_3$	98.89 - .374	86.56 - 1.26	73.05 - 1.43	30.22 - 1.94
Check	96.39 - 1.50	82.22 - 2.91	65.60 - 3.22	30.77 - 3.46
Difference	2.50 - 1.04	4.34 - 2.14	7.45 - 2.39	.55 - 2.67

TABLE 27-A

Chesapeake Strawberries, 1930

J. F. Parker's

Treatment	Per cent Sound Average of Six Boxes: First Inspection	Second Inspection	Third Inspection	Fourth Inspection
$NaNo_3$	97.77 - .559	95.29 - 3.07	80.03 - 2.47	70.36 - 4.55
Check	96.63 - .702	95.10 - .65	78.67 - 2.57	65.38 - 3.01
Difference	1.14 - .605	.19 - 2.11	1.36 - 2.40	4.98 - 3.68

TABLE 28.

Strawberry Results

1930.

Premier at Eshams

Treatment	Date	Total Sugars	Reducing Sugars	Sucrose	Acid Hydrolyzable Material	Dry Weight	Total N.	Pectin as Calcium Pectate: Total	Soluble	Proto
$NaNo_3$	May 25							.606	.387	.219
"	May 27	52.89	41.50	11.39	6.35	12.114	.137	.376	.252	.124
Check	May 25							.567	.412	.155
"	May 27	47.29	41.13	6.16	5.75	12.348	.105	.552	.441	.111

Chesapeake at Parkers

$NaNo_3$	May 26							.468	.286	.182
"	May 29	44.31	41.05	3.26	7.32	10.525	.125	.585	.398	.187
Check	May 26							.525	.319	.206
"	May 29	45.17	42.38	2.79	8.32	9.689	.113	.574	.438	.136

Chesapeake at Shockleys

$NaNo_3$	May 28							.543	.360	.183
"	May 31	42.22	41.03	1.19	6.88	10.022	.136	.606	.349	.257
Check	May 28							.522	.339	.183
"	May 31	42.33	41.42	.91	7.68	9.898	.137	.531	.340	.191

acid hydrolyzable material content were caused by the difference in the rate of water loss. On the other hand, the difference in the rate of water loss has reduced the difference in the sucrose and total nitrogen content. Both these constituents were increased by the addition of nitrogen fertilizers to the soil.

Summary for Parker's Chesapeake. Two years study of the fruit from this patch indicates that the addition of fertilizers to the soil has resulted in no change in the amount of softening of the fruit in storage.

The rate of water loss of the fruit while in storage appeared to be greater for the fruit from the nitrated plots. The rate of water loss was so great as to mask the changes in the pectin materials during ripening. Nitrogen fertilizers have resulted in an increase in the total nitrogen content and in the sucrose content, but have resulted in no change in the content of total sugar, reducing sugar or acid hydrolyzable material content.

CHESAPEAKE AT SHOCKLEY'S

The plants in this field were set out in the spring of 1929 in the Pittsville section of Wicomico County -- the fertilizer plots being organized during the spring of 1930 as the plants entered their first fruiting season.

The soil was a level Portsmouth fine sandy loam in a moderate state of fertility. There was a fair stand

of plants and few weeds. Each plot consisted of five rows, two hundred and sixty feet long. The rows were 3.7 feet apart giving each plot an area of one-ninth of an acre.

Investigations Conducted in 1930

Six boxes of fruit were picked from the plot receiving sodium nitrate and six boxes from the check plot about the middle of the season. The fruit was packed into a regulation strawberry crate and hauled about five miles by car, and kept in a well ventilated room of a dwelling house.

The fruit was examined four times during the ripening process. At each examination the soft berries were discarded, and a sample of the sound berries was preserved for determination of the pectic constituents. In addition to the pectin sample, a sample was preserved for carbohydrate and nitrogen analysis at the last examination.

The results of the storage counts are presented in table 27. The difference in the percentage of sound fruit between the check and fertilized plots was not significant at any inspection. The results of the chemical analyses, table 28, indicate that there was an increase in the quantity of protopectin. This was no doubt an apparent increase, the real cause being a loss of water from the fruit. The percentage dry weight was greater for the fertilized fruit than for the check fruit.

The differences in the quantity of total sugars, reducing sugars and acid hydrolyzable materials for the two treatments are small. These differences are no doubt caused to a large extent by differences in the amount of water lost by the fruit from the two plots. The sucrose content is greater for the fruit from the fertilized plots than for the fruit from the check plot. This difference has been lessened by the difference in amount of water lost.

The total nitrogen content of the fruit was not changed by the addition of fertilizer to the soil in this planting.

Summary of Chesapeake at Shockley's. One year's results at this place indicate that nitrogen has caused no change in the amount of softening of the fruits in storage. Nitrogen applications have resulted in a greater water loss from the fruit in storage. It has resulted also in an increase in the sucrose content of the fruit. No other changes in the composition of the fruit were apparent.

General Discussion of Strawberry Investigations

The results obtained during this three year study indicate a strong influence of climatic conditions on the carrying quality of strawberries. In 1928,a fairly wet season, rains were prevalent during the harvesting season. As a result many berries decayed during the storage tests.

There was a tendency during this rainy season for more decayed berries to develop in the sample from the fertilized plots than in the sample from the check plot. This increased amount of decay was probably due to the greater foliage on the nitrated fruits which caused the berries to remain damper following rains.

The seasons of 1929 and 1930, on the other hand, were dry seasons, very little rain fell during harvest. As a consequence very few berries decayed from any of the plots.

During these seasons keeping quality was measured largely by the amount of softening in storage. During the dry season no differences were evident in the keeping quality of the fruit, which could be attributed to the fertilizer treatments.

Shoemaker and Greve (35) report that fruits from plots which received nitrogen were slightly softer than fruit from check plots. However, their differences in pressure test are very small and were not correlated with results of shipping tests which showed no differences. Kimbrough (20) indicates that weather conditions, especially amount of rain, exerts a greater effect on the composition of strawberries than do the fertilizer treatments.

Weinberger (38) has shown that potash fertilizers do not influence the keeping quality of strawberries as measured by storage counts.

Chemical studies indicated that protopectin changes

were not a reliable measure of storage changes. There was an apparent increase in protopectin which probably was due to a loss of water from the fruit during storage. Unfortunately no moisture determinations were made on the material for pectin analysis. It seems probable that if the pectin analyses were based on the original fresh weight of the fruit at picking time, changes in the protopectin content might prove a reliable measure of the softening process in strawberries. Pectin analyses, as made in this investigation (see appendix) would not prove practical from a commercial standpoint to predict storage life because of the time required to complete a determination. If some accurate microchemical method were available the pectin changes would probably be a valuable index of the ripening process.

Although the application of nitrogen to the soil has generally resulted in an increased nitrogen content of the fruit there has been no corresponding change in the susceptibility of the fruit to decay or in the amount of softening.

Summary of Strawberry Investigations

A three years study of the influence of nitrogen fertilizers on the storage and keeping quality of fruits has shown that in a wet season there may be a slightly greater amount of soft and decayed fruit from the fertilized plots if the fruit is shipped far at high temperatures. If the fruit is shipped with refrigeration or

is held at cool temperatures there is no increase in the amount of decayed or soft berries caused by fertilizer treatments.

Likewise, in a season of normal rainfall the fertilizers exert no influence on the keeping quality of the fruits.

The Chesapeake variety showed an increase in dry weight with nitrogen fertilizer while the Premier showed a decrease. An increase in the nitrogen content of the fruit has not resulted in a change in the keeping quality of the fruit. Pectin changes might possibly be used as a criteria of keeping quality if determinations were based on the original fresh weight of the fruit, but this relationship has not been studied.

III. PEACH INVESTIGATIONS

Fertilizer plots were located in a commercial Elberta orchard located on a Manor loam soil* near Frederick, in Frederick County, Maryland. Although this study was made during the fruiting seasons of 1928, 1929, and 1930, the trees had been receiving their respective fertilizer treatments since the spring of 1922. As a result the trees were in the state of vigor which was caused by the different fertilizers which were applied.

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*Soil Survey of Frederick County, Maryland, by Bureau of Soils, U.S.D.A. in Cooperation with the Maryland Geological Survey and Maryland Agricultural Experiment Station.

General Methods of Study

Sampling. The samples for storage were selected in the same manner as for apples, previously discussed, being selected for uniformity of color and maturity, in the same way fruit is picked by a grower who carefully spot-picks his fruit.

Pressure Testing. Pressure test studies were begun in 1928, using a tester which was developed by Culpepper and Magoon of the U. S. Department of Agriculture for sweet corn. Caldwell of the U. S. Department of Agriculture used it for peaches, but for this study it did not prove adequate. The principal difficulty with this tester was that the plunger (1/32 inch in diameter) did not cover a great enough surface. As great differences were obtained in successive pressure tests, of the same fruit, even though made close together, as between pressure tests of hard ripe and soft ripe fruit. A number of tests were made during 1928, using this tester but the results were too variable for any conclusions, so have not been included in this report.

In 1929, the Blake peach tester (5) was used. The plunger of this tester had a greater surface (3/16 inch in diameter) than the corn tester and proved quite satisfactory for measuring the softenss of the fruit.

The fruits were pressure tested with the skin on because it was felt that the skin and the cells directly

beneath it were important parts involved with the shipping quality of the fruits. Recent work by Addoms, Nightingale, and Blake (1) has confirmed this assumption. They show that with the Elberta peach there is a layer, a few cells in thickness, just below the epidermis which are much smaller and closer together than the cells below. In removing the skin these closely packed cells would be removed leaving the large, loosely packed cells for the pressure test.

A sample for pressure testing, consisted of thirty peaches selected at random from the storage sample. Six tests were made on each peach, including one test on each cheek and two tests near the suture and two tests nearly opposite the suture.

Immediately after completing a pressure test determination for a plot, samples of these fruits with the skin removed were preserved for chemical analysis. Detailed descriptions of the chemical method are given in the appendix.

ELBERTA PEACHES, MOUNT AIRY, MARYLAND

Description of Orchard and Plots. This orchard is owned by the Walker Orchard Company at Mount Airy, in Frederick County, Maryland. It is located on a Manor loam soil and a system of clean cultivation is practiced. The trees were planted in 1922, and the fertilizer treatments were begun soon after planting. The trees in this

orchard have responded to the application of nitrogen as is seen in table 1. The differences in growth are not as marked as they were during the earlier years of the experiment. This is because of the stimulus to the check trees by some cross feeding and because of the retarding effect which fruiting has had on the growth of the fertilized trees. A definite response to potash and phosphorus in this orchard has been noted by Auchter and Schrader (4). Applications of phosphorus in addition to nitrogen did not result in an increased growth or yield, but potassium in addition to nitrogen resulted in an increased growth and yield. When phosphorus was applied in addition to nitrogen and potassium, both growth and yield were markedly increased. This is the only orchard connected with this investigation in which phosphorus or potassium has exerted any influence on either the growth or yield. When the storage studies were started (1928) the trees in this orchard were six years old and in a good condition of growth. The check trees were smaller and less vigorous than the nitrate trees.

Investigations Conducted in 1929

The crop in 1929 was light but the fruits were well distributed over the trees so that uniform samples of fruit were secured. Duplicate samples of one bushel each were secured from the check plot. These fruits were compared with similar samples of fruit taken from the plots receiving five pounds and one and one-half pounds of sodium nitrate per

tree respectively. A few fruits were taken from each tree in the plot, for the storage sample. The samples were held in an open shed for five days — August 23 to August 28 — pressure tests being made at daily intervals.

Results. The results obtained in 1929 indicate that at picking time the fruit from the no-nitrate plot was about 0.7 of a pound softer, as measured by the Blake peach tester, than the fruit from the nitrated plots.

TABLE 29

Firmness of Elberta Peaches in 1929

Picked August 23, Held in Open Shed., Pressure Tested With Blake Peach Tester

Treatment	Aug.23	Aug.25	Aug.26	Aug.27	Aug.28	Difference.
$NaNO_3$ 5#	8.93	6.80	5.25	3.65	3.15	5.78
$NaNO_3$ 1-1/2#	9.18	8.26	7.43	6.26	4.72	4.46
No Nitrate	8.34	6.23	5.07	4.11	3.38	4.96

There was not much difference in the firmness of the fruits from the nitrate plots whether the trees received one and one-half pounds of sodium nitrate or five pounds per tree; fruit from the plot receiving one and one-half pounds being about 0.2 of a pound firmer. By the second day in storage (August 25) this difference had increased, fruit from the plot receiving one and one-half pounds of sodium nitrate per tree testing better than a pound firmer, at this time than frot from the no

nitrogen plot, or from the plot receiving five pounds of sodium nitrate per tree. The change in firmness is greatest for the fruit from the five-pound-per-tree plot and least for the one and one-half-pound-per-tree plot. The greater firmness throughout the season for the fruit from the plot receiving one and one-half pounds of nitrate per tree is caused to a certain extent by the difference in firmness at picking time. However this cannot account for all the difference in the firmness of these fruits.

Summary. At picking time fruits from the no nitrate plot was 0.7 of a pound softer than fruit from nitrated plots. There was practically no difference in the firmness of fruit from plots receiving one and one-half pounds of sodium nitrate as compared to fruit from plots receiving five pounds. After five days in storage the fruit from the plot receiving one and one-half pounds tested more than a pound firmer than fruit from either of the other plots.

Investigations Conducted in 1930

There was a light blossom in this orchard in 1930, though a uniform crop of fruit was produced. The fruit was not large, however, because of the dry season.

Pressure Test Studies.

On August 23, 1930 triplicate samples of one bushel each, were secured from the plots receiving five and

ten pounds of sodium nitrate per tree respectively and also from the check plot. These fruits were held for four days in an open shed, pressure tests being made at daily intervals on thirty peaches from each basket.

Results. The results of the pressure test studies are given in table 30. At the time of picking and for the two succeeding days, the firmness of the fruits from the different plots varied a little but no significant differences were evident. By September 2 the fourth and

TABLE 30

Firmness of Elberta Peaches in 1930

Picked August 30, Held in Open Shed. Pressure Tested With Blake Peach Tester

Treatment.	Basket	Aug. 30	Aug. 31	Sept. 1	Sept. 2
$NaNO_3$ 10#	1	7.00	6.09	4.24	3.26
$NaNO_3$ 10#	2	7.04	5.94	3.87	3.20
$NaNO_3$ 5#	1	7.08	5.66	4.03	2.90
$NaNO_3$ 5#	2	7.56	5.85	4.03	2.90
$NaNO_3$ 5#	3	6.93	5.15	3.88	2.82
Check	1	7.04	5.73	4.47	3.21
Check	2	7.14	4.87	3.41	3.03
Check	3	7.11	5.93	3.72	3.45

the last day in storage, the fruit from all plots was ripe. Fruits from the plot receiving five pounds of sodium nitrate per tree tested about 0.3 of a pound softer than fruits from the check plot or from the plot which received ten pounds of sodium nitrate per tree. While this difference is consistent,

being evident in all three baskets, it is rather small (0.3 pound) and is of doubtful importance.

Summary. At picking time and during the first three days of storage there were no differences in the firmness of the fruit from the nitrated plots as compared with the fruit from the check plot. On the last day in storage the fruit from the plot receiving five pounds of sodium nitrate was a trifle softer than fruit from the check plot or fruit from the plot receiving ten pounds of sodium nitrate per tree. The difference in firmness (0.3 pound) is not commercially important.

Chemical Studies

Chemical samples were preserved from the same fruit which was pressure tested. Pectin samples were taken each day, while samples for carbohydrate studies were taken on the last day in storage. Detailed methods of chemical procedure are given in the appendix.

Results The chemical data are shown in table 31. There was a slightly greater decrease in the protopectin content of the fruit from the plot which received five pounds of sodium nitrate per tree as compared with fruit from the check plot or from the plot receiving ten pounds per tree. Fruit from this plot also became softer than fruit from the other two plots as noted in the discussion of the pressure test data.

The addition of nitrogen has apparently increased the amount of total sugars, sucrose, and dry weight, but

TABLE 31.

Elberta Peaches 1930.

Treatment.	Total Sugars	Reducing Sugars	Sucrose	Acid Hydrolyzable Material	Pectin as Calcium Pectate: Total	Sol	Proto	Nitrogen	Dry Weight	Ph	c.c. alkaline to neutralize 10 c.c. sap.
$NaNO_3$ 10# Aug.30					1.078	.242	.836			3.36	74.95
" Sept.2	56.66	19.47	37.19	6.81	1.174	.509	.665	.45	18.248	3.42	72.95
$NaNO_3$ 5# Aug.30					1.072	.270	.802			3.31	72.50
" Sept.2	57.21	21.93	35.28	7.24	1.120	.517	.603	.46	17.817	3.52	70.60
Check Aug. 30					1.054	.243	.811			3.35	74.50
" Sept. 2	55.91	20.61	35.30	7.01	1.176	.548	.628	.47	17.888	3.45	72.35

has decreased the quantity of reducing sugars. It total quantity were considered, the differences would be greater for total sugars and sucrose and less for reducing sugars than are present on a dry weight basis. There appears to be no correlation between nitrogen application and acid hydrolyzable material.

Contrary to the results obtained by Nightingale, Addoms and Blake (30) with Elberta, there were no differences evident in the amount of nitrogen in these fruits. No significant differences were shown by the fruits in Ph of the juice. All fruits showed a slight increase in Ph from the hard ripe to the soft ripe condition. The total acidity decreased as the ripening progressed. The change in acidity was about the same for the fruits from all plots, however the actual acidity was about three per cent less for the fruit from the single nitrogen plot than for the fruit from the other two plots.

Summary. Applications of nitrogen have had no effect on the nitrogen content of the fruits, but have resulted in an increase in dry weight, and total sugars. Reducing sugars, on the other hand, were less in the fruit from plots which were fertilized with nitrogen.

Summary of Results Obtained With Elberta

Nitrogen applications have not caused a consistent change in the firmness of the fruit at picking time or

in storage, as measured by the Blake Peach tester. Furthermore nitrogen applications have not caused a change in the nitrogen content of the fruit, but have resulted in an increase in total dry weight and total sugars. There has been a reduction in the quantity of reducing sugars associated with applications of nitrogen.

Nitrogen fertilizers have caused no significant changes in the total acidity of the fruit or in the Ph of the juice.

GENERAL SUMMARY

1. The investigation during three years included studies on the pressure test, pectin changes, general carbohydrate and nitrogen content, rate of respiration, changes in acidity and Ph and the behavior of fruits in storage, as affected by the application of nitrogen fertilizers.

2. Nitrogen fertilizers have not caused a consistent change in the firmness of apples, peaches or strawberries at picking time or in storage.

3. Application of nitrogenous fertilizers has resulted in increased nitrogen content of apples and strawberries.

4. Associated with the increased nitrogen content, has been an increase in sugar content with apples, while the results with strawberries varied with varieties. Sucrose content of strawberries was increased by application of nitrogen.

5. An increased rate of respiration of apples was associated with increased applications of nitrogen.

6. Nitrogen applications have delayed the maturity of both peaches and apples.

7. Fertilizers have had no influence on the content or changes in pectin materials, except indirectly by their effect on maturity.

8. Nitrogen applications to apples, peaches and strawberries have had no effects of commercial importance

onthe shipping quality or keeping quality, as measured by pressure tests, storage counts and chemical studies.

GENERAL CONCLUSIONS

Nitrogen applications to apples, peaches and strawberries in Maryland have caussd no changes of commercial importance in the firmness of the fruit at picking time or in the keeping quality of the fruits. The chemical composition of the fruits has been affected, such as increased nitrogen content and increased sugar content, but these changes have not affected the keeping quality.

Although a higher respiration rate of apples has been associated with applications of nitrogen, this is assumed to be caused by the increased sugar content rather than to an inherent effect of the nitrogen, since no measurable effects on keeping quality were found associated with the increase in respiration.

The results reported in this paper apply to the actual effects of nitrogen on the keeping quality when other factors are removed, and do not take into consideration any indirect effects, such as the effect on size, color, etc. which naturally affect keeping and shipping quality. It is felt that these factors can be controlled by proper orchard management to avoid adverse effects of nitrogen on size and color of fruit.

The results obtained indicate that a grower should feel free to use nitrogen to increase his crop and tree growth but that a certain amount of care should be directed

to other orchard problems in order to avoid the production of excessively large, poorly colored fruits and to prevent the harvesting of immature fruit.

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APPENDIX

Chemical Methods

Method of Sampling for Chemical Analysis

Uniform fruits were used which had just been pressure tested. A 100 gram sample was taken of the flesh of the fruits, using fifteen to twenty apples, or thirty to forty peaches and strawberries. The fruits of apple and peach were pared and cut into small pieces, while the strawberries were quartered. Enough ninety-five percent alcohol was used so that the final concentration was eighty per cent. The required amount of alcohol was placed in a 500 cc. wide mouthed flask, placed on a torsion balance and counterbalanced by a similar flask of alcohol. Calcium carbonate (0.5 grams) was added to each flask. As fast as the pieces of fruit were cut they were dropped into this alcohol. When one-hundred grams had been added, the flask was immediately transferred to a water bath held at 80°C. The alcohol was allowed to boil gently for five minutes. After the flasks had cooled they were stoppered and sealed with paraffine.

Samples for pectin analysis were taken in the same manner with one exception. They were not boiled.

All samples were taken in duplicate.

Dry Weight

The alcohol was carefully decanted into a 500 cc.

volumetric flask while the residue was dried at 70°C. for forty-eight hours. The preserving flask and the evaporating dish in which the residue was dried were washed carefully with eighty per cent alcohol and the washings added to the volumetric flask, which was then made to volume with eighty per cent alcohol. An aliquot was drawn from this flask, after thorough shaking, placed in a previously weighed beaker and dried at 70°C. After forty-eight hours the beaker was allowed to cool in a dessicator for thirty minutes and weighed. After the residue was dried and weighed it was ground so it would pass throudh a sixty mesh screen. The sample was then stored in a sample bottle until needed. Before withdrawing an aliquot of this for analysis it was placed in the 70° oven for ten or twelve hours.

Reducing Sugars

Two aliquots were extracted at one time, one for starch and one for acid hydrolyzable substances. The size of the aliquot was determined by the amount of starch and acid hydrolyzable material present, and then diluted to the proper concentration for reducing sugars.

The two aliquots were weighed out and placed in two extraction shells which were stoppered with glass wool. Aliquots of the alcohol fraction exactly equal to those placed in the shells were placed in a 250 cc. Erlenmeyer

flask. If the volume of alcohol was less than 150 cc. it was made to this volume with eighty per cent alcohol. The shells were placed in a Soxhlet extraction tube which in turn was connected with the Erlenmeyer flask, and with a condenser. The flask was placed on a sand bath and refluxed for three hours. The heat was so regulated that the Soxhlet tubes tripped about every ten minutes.

Duplicate determinations were made of each field sample.

Following the extraction the shells were placed in the oven at 70°C., while the flask was placed on a sand bath, and the alcohol evaporated. Evaporation was hastened by blowing air into the flask.

When the alcohol was entirely driven off, the contents of the flask were carefully washed into a 250 cc. volumetric flask. A few drops of neutral lead acetate were used for clearing.

The solution was then made to volume with distilled water and filtered, de-leaded with potassium oxalate and again filtered. An aliquot of this was used for the determination of reducing substances by the Bertrand modification of the Munson-Walker method. All carbohydrates were calculated as destrose.

Total Sugars

An aliquot of the solution used above was placed in a 100 cc. volumetric flask and hydrolyzed for twenty-four

hours with 2.5 per cent hydrochloric acid at room temperature. After hydrolysis, the solution was neutralized with 0.1 N sodium hydroxide using litmus paper as the indicator. It was then made to volume and an aliquot taken for the determination of reducing substances as outlined for reducing sugars.

Starch

After the shells were dried, the larger aliquot was removed and ground with quartz sand until it would pass through a 100 mesh screen and placed in a 250 cc. beaker. Enough cold water was added to thoroughly moisten the material, then 50 cc. of boiling water was added and the entire mass boiled for a few seconds, then placed on a boiling water bath for one hour. After cooling at 50°C., five cubic centimeters of saliva (diluted one to three) were added and the beaker held at 50°C for one hour. After one hour the enzyme was inactivated by placing the beaker on the water bath for fifteen minutes. Another 5 cc. of saliva was added and the procedure repeated. If a microscopic examination showed starch to be present, the procedure was again repeated. If no starch remained the material was transferred to a 250 cc. volumetric flask and precipitated with 95 per cent alcohol, made to volume with 80 per cent alcohol and filtered. An aliquot of the filtrate was placed in an Erlenmeyer flask and the alcohol removed on the sand bath.

The volume was made up to 100 cc. by the addition of water, 10 cc. of hydrochloric acid (specific gravity 1. 125) was then added and the mixture refluxed for two and one-half hours. After cooling, the material was neutralized, transferred to a 250 cc. volumetric flask and made to volume. An aliquot was drawn from this and the reducing substances determined as for reducing sugars.

Acid Hydrolyzable Material

The smaller aliquot extracted for sugar determinations was transferred to a 500 cc. Florence flask, 100 cc. of distilled water added, and 10 cc. of hydrochloric acid (specific gravity 1.125). The material was refluxed for two and one-half hours, cooled, neutralized, transferred to a 250 cc. volumetric flask, made to volume and filtered. An aliquot of the filtered extract was used for the determination of reducing substances as outlined under reducing sugars.

Nitrogen

An aliquot of the alcoholic material was placed in a 500 cc. Kjeldahl flask and evaporated down to a thick paste. Then a similar aliquot of the dried sample was added and the nitrogen determined by the Kjeldahl-Gunning method with the modification to include nitrates.

Pectin Materials

The alcohol was filtered from the sample, the

preservation flask washed with eighty per cent alcohol, and this passed through the filter. The alcohol was discarded and the residue was dried on the filter paper for forty-eight hours at 70°C. It was then ground and divided into two equal parts, one for the determination of soluble pectin and one for total pectin.

Soluble Pectin. One-half of the sample was placed in a 1000 cc. Florence flask and 500 cc. of water added. The flask was then tightly corked and shaken for one hour by means of a mechanical shaker. After shaking, the material was filtered and duplicate aliquots of the filtrate placed in 800 cc. beakers. Enough water was added to bring the volume to 390 cc. Ten cubic centimeters of normal sodium hydroxide were added and the material allowed to stand over night.

The following day 50 cc. of normal acetic acid were added followed by 50 cc. of molar calcium chloride, added slowly with stirring. The pectin was precipitated as calcium pectate. After standing for one hour the material was brought to a boil and filtered. The residue was washed with hot distilled water until free from chlorides, then transferred to a weighed beaker and dried at 100°C. for twenty hours. After removal from the oven the beaker was cooled in a dessicator for thirty minutes and weighed, the results are expressed as per cent calcium pectate.

Total Pectin The other half of the sample was transferred to a 250 cc. Erlenmeyer flask and 100 cc.

of water added. The flask was then connected with a condenser and the material refluxed for thirty minutes, filtered by means of suction while hot, and the residue placed again in the flask. This time 100 cc. of thirtieth normal hydrochloric acid were added and the material refluxed for another thirty minutes and filtered as before. The filtrates from the water and acid hydrolysis were kept separate. The material was refluxed three times with acid, the filter paper being transferred to the flask with the residue each time.

After the third acid refluxing, the filtrates were added together and made to volume in a one-liter volumetric flask. A suitable aliquot was withdrawn, placed in an 800 cc. beaker, and neutralized with NaOH, then made up to 390 cc. with distilled water and 10 cc. of normal sodium hydroxide added. From this point the procedure was the same as for soluble pectin.

Total Acidity

This was measured by titrating a solution, containing ten cubic centimeters of juice, with standard alkali using phenolphthalein as the indicator. Freshly expressed juice was used.

Ph of Juice

The Ph was determined with a Youden Hydrogen-ion Concentration apparatus. This is equipped with a quinhy drone electrode and a potassium acid phthalate standard cell.

The freshly expressed juice was used for this study.

Respiration Methods

The respiration apparatus used (figure 10) was similar to that described by Harding, Maney, and Plagge (14).

About seven kilograms of fruit was used in each jar, while each fertilizer treatment was represented by two jars. Enough sodium hydroxide was used in the absorption tubes, so that all the carbon dioxide liberated by the fruit in twenty-four hours would be absorbed. After a twenty-four hour run, the tube was washed into the flask and the alkali was titrated with standard acid. The carbon dioxide absorbed by the alkali was measured by getting the quantity of acid necessary to change the Ph from 9 (Phenolphthalein end-point) to 4 (Methyl orange end-point). Results were tabulated as milligrams of carbon dioxide liberated per kilogram-hour of fruit.

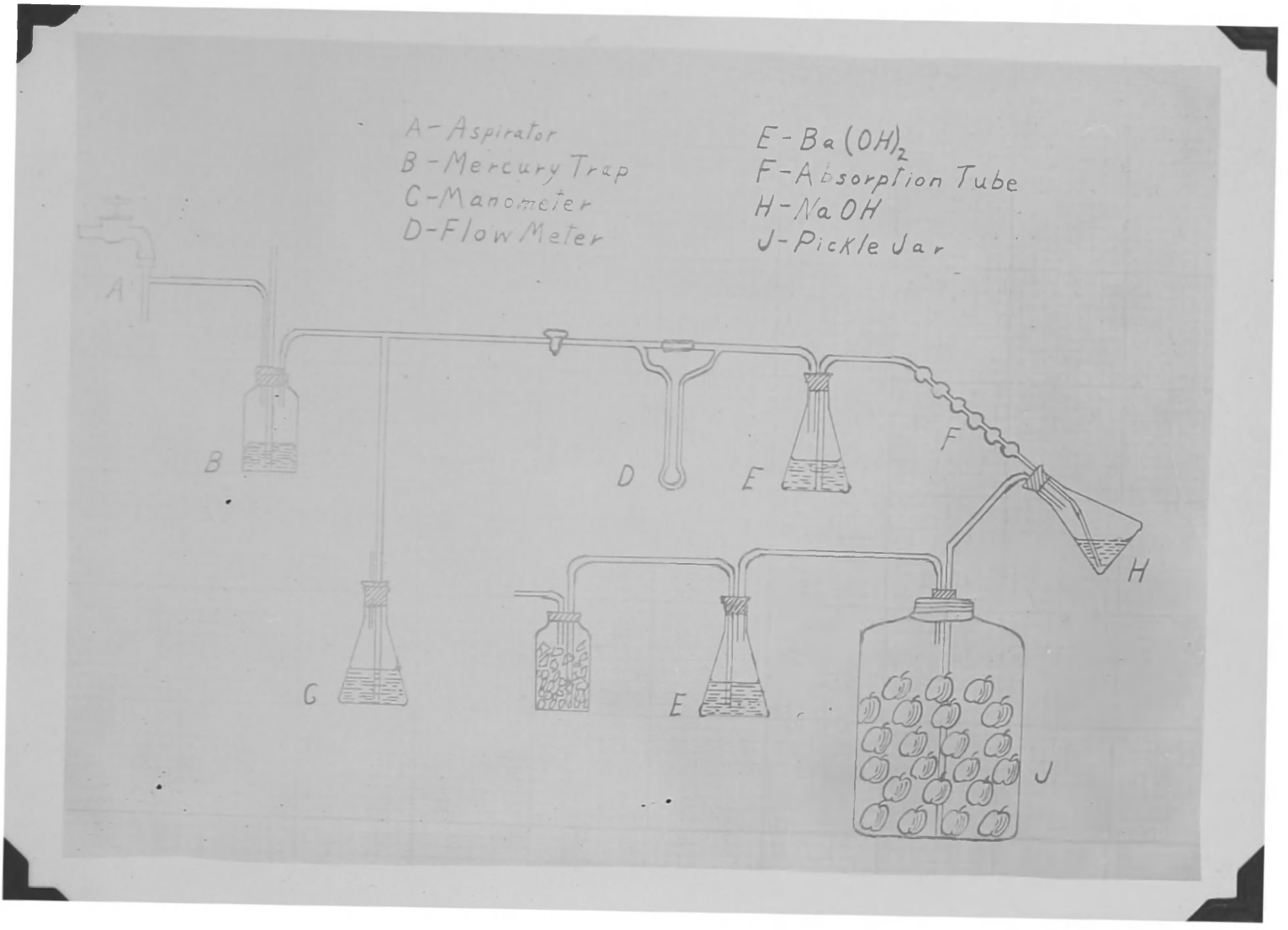

Figure 10.

Diagram of a Unit of the Apparatus Used in the Respiration Studies.

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